DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

British Industries Fair

THE final British Industries Fair held in London was the first to receive the full co-ordinated support of the chemical industry through the Association of British Chemical Manufacturers. More than a hundred member firms took part. At the end of the exhibition the general opinion appeared to be that attendance was not up to expectation, although official figures for the number of buyers did not show a marked decrease compared with 1955. The problem with all exhibitions, however, is not the number of visitors who are attracted to the stands and take away the expensively printed literature, but their quality. Ten visitors of the right kind are many times more important than a thousand wanderers who casually wend their way from stand to stand. Many people believe that there is a real need for a first-class specialist fair for the chemical industry to be held in London. Such a fair would not have the wide general appeal of the mammoth B.I.F., but it would have much more chance of attracting the serious-minded buyer. The possibility of integrating the chemical plant manufacturers into such a fair should obviously be considered.

Russian Bid for Chemical Equipment

BRITISH industry stands to gain orders worth many millions of pounds, if the offer of trade to the tune of £200 million a year that the Russians made at the end of the Bulganin-Krushchev mission does materialise. At present British exports to Russia add up to about £23 million a year. The Soviet Embassy has issued a detailed list of the industrial equipment which accounts for the £200 million total. This includes equipment for the rubber and chemical industries. Specifically mentioned are compressors that are required for chemical plants and ultra-high pressure valves. Another large item is engineering equipment for production of Terylene and polythene. The Russians point out the need for the 'normalisation' of Soviet-British trade relations and the elimination of 'discrimination' if their offer is to prove fruitful. This means, of course, the removal of our embargo on certain items at present on the strategic list. Sir Anthony Eden has declared that two-thirds of the Soviet shopping list is unaffected by strategic restrictions, and he has gone so far as to suggest that the percentage may well turn out to be even higher in practice.

Record U.K. Detergent Output

OVER 250,000 tons of synthetic detergents were produced in the United Kingdom in 1955. Of this figure more than 50,000 tons were exported, earning just over £6.6 million. Sales of these products, obtained largely from petroleum derivatives, account for 37% of all soaps and detergents used in this country and are equivalent to a per capita consumption of over 7lb. Britain is now the second largest world user of synthetic detergents, following the United States, where sales of these products account for about 60% of annual consumption of all soaps and detergents. The expansion during the last three years has been gradual but at the expense of the older soaps, the production figure of which now stands at 400,000 tons. In London recently the president of Procter and Gamble, parent company of Hedley's, launched a bold counter-attack on those who have criticised the high-powered advertising campaigns for detergents. He said that advertising is the most economic salesman of such mass-produced goods yet discovered. Recently disclosed figures show that in the U.S.A. Procter and Gamble spend more on advertising than the whole of General Motors, which is the largest industrial combine in the world, and most of the money is spent on the detergent side.

Engines as Chemical Reactors

THE idea of carrying out chemical reactions in power-producing machines such as piston engines or turbines is always thought-provoking, and chemical engineers will doubtless be interested in the news of research being conducted in the U.S.A., France and the U.S.S.R., upon a revolutionary type of reactor based upon the piston engine. The *Transactions of the Institution of Chemical Engineers* reports that two American research workers, Dr. B. H. Sage and P. A. Longwell, of the California Institute of Technology, have used a free piston engine and have succeeded in reaching temperatures approaching 6,000°C and pressures of 7,000 atmospheres within one thousandth of a second. They expect that this new reactor may lead to a new technique of producing many well-known chemicals.

Clear Britain's Skies

ONE provision of the Clean Air Bill, which will have far-reaching consequences if it goes through, is that industrial processes which present special technical difficulties in the disposal of their effluents should fall within the sphere of influence (and action) of the Alkali Inspectors. Without doubt public opinion, as well as expert opinion, favours strong official moves calculated to reduce the extent to which Britain's skies are despoiled by smoke and grit. In this context it is welcome news that the British Iron and Steel Research Association, in conjunction with the British Standards Institution and the Iron and Steel Federation, is engaged upon research with the aim of finding methods of abatement of the atmospheric pollution caused by open hearth furnaces and sinter plants.

The investigations have followed two main courses: the first is concerned with the measurement and standardisation of smoke control and grit emission; the other is directed towards equipment for controlling abatement. The second line of research has drawn attention to the problem of removing iron oxide from the smoke emitted

by the furnaces. This is a difficult matter because of the very small size of the iron oxide particles that are involved. In one method that is being tried the particles are made to act as nuclei for the condensation of water vapour, and the resultant water droplets enclosing the particles can then be removed.

Boosting Chemical Synthesis with Gamma Rays

THE radiation work being done in the new Rideal Laboratories of Monsanto at Newport attracted particular attention from the visitors who attended the official opening of these laboratories by the president of the Royal Society, Sir Cyril Hinshelwood. As reported in our last issue, work is being done there on irradiated plastics. The Newport scientists are also interested in the harnessing of γ irradiation to promote various chemical reactions, including alkylations, halogenations, oxidations and isomerisations. The possible industrial use of this technique for promoting reactions will be brought nearer by such investigations, which will shed light on the important economic question: What is the yield of reaction product per unit of radiation absorbed? The initial research programme at Newport was planned to use two 60-curie sources of cobalt 60. The design of the laboratory has now been modified so that a more powerful source of radio-cobalt can be used, and in addition a caesium source of up to 1,000 curies.

A Focus for Instrument Technologists

THE Society of Instrument Technology has expanded rapidly since its foundation in 1945, and now has a membership of nearly 1,400. This growth is largely the result of the untiring efforts of honorary officers, working without a full-time staff or permanent London headquarters. Now a full-time secretary has been engaged, and S.I.M.A. is providing an office for the society at 20, Queen Anne St., London, W.1 (LANgham 4251). The secretary is Commander A. A. W. Pollard, D.S.C., R.N. (Retd.), who in recent years has held a number of naval staff and administrative appointments and been much concerned in research and development. Dr. Harold Moore remains the society's Hon. Editor for the time being.

No Shortage of Uranium

FUTURE requirements for nuclear energy are assured both by the present known reserves of uranium in territories belonging to countries in the Western world, which amount to many millions of tons, and the new prospecting schemes at present under way. This was the outstanding point made by Mr. S. H. V. Bowie, chief geologist of the Geological Survey's Atomic Energy Division, in his contribution to the special atomic energy supplement produced by *The Financial Times*. The basic techniques of prospecting—geochemical, geophysical and geobotanical—for other metals may also be applied to the quest for uranium and thorium.

Uranium, currently the most important atomic fuel, constitutes an estimated 0.0003% of the earth's crust. Among the most important deposits now being worked are those of the Great Bear Lake, Lake Athabaska and Blind River in Canada; Shinkolobwe in the Belgian Congo; the Witwatersrand in South Africa; and Rum Jungle in Australia. The present tendency is to extract low-grade ores capable of being worked on a vast scale rather than use the smaller high-grade pitchblende lodes. Considerable advances have been made in the last few years in extraction techniques using ion-exchange resins on low-grade ores and South African gold mine residues.

The Danger of Non-Experts

THE president of the Institution of Chemical Engineers, Mr. Oriel, has made a strong plea for more technical experts to be represented in the top levels of administration; he mentioned in particular the lack of such experts among the leaders of the nationalised industries. At the Institution's dinner Sir John Maud, the Minister of Fuel and Power, quoted a *bon mot* of Lord Cherwell's, which underlined Mr. Oriel's point. Here is Sir John's version of a good Cherwellism: "The trouble with the non-scientists in the British Cabinet is that they believe any nonsense that a scientist tells them."

Coal in the Atomic Age

LIGHT-HEARTED and amusing though Sir John's speech was it ended on a very serious note. He referred to coal, and appealed to technologists to study this pre-Atomic Age mineral and its combustion. We agree with him that it would be a grievous mistake if technological talent is concentrated on oil and atomic power to such an extent that coal is neglected. For, as he remarked, we in Britain will need coal for a very long time yet. The Fleck committee made it clear that big changes were needed on the management side of the National Coal Board, and according to the board's chairman the general managerial structure envisaged by that committee has now been brought into being. But the output of coal still lags far behind requirements. The mines produced 21 million tons in 1955, nearly 4 million less than in 1954. Consumption was up by 1,400,000 tons, and the gap between output and consumption had to be filled by the importation of 11,600,000 tons. The loss on the latter was £13,600,000, out of a total deficit on the year of £19,600,000.

We are now promised a further increase in the price of coal. Dearer coal is always said to stimulate more efficient coal utilisation. In actual fact the cost of coal is a relatively small item in most manufacturing processes, so that it would be better to forget about increased price being an incentive to coal saving, and concentrate upon the need to gear a greater technological effort to the problems connected with coal winning and coal utilisation. All kinds of helpful ideas are mooted, but they need sorting out by technical experts before the useful ones can be developed and put into operation. For example, a few weeks ago Dr. R. Lessing told an S.C.I. conference that some use ought to be made of the 40 million tons of colliery waste which accumulate each year and which contain the equivalent of 10 million tons of saleable coal. Whether that source of coal can be profitably exploited is primarily a technical question, like dozens of other questions which cannot be answered until coal receives the technological attention which it demands. If necessity is still the mother of invention, then some really good and productive ideas ought to emerge from this month's conference at Cheltenham which will discuss the contribution of the chemical engineer to the coal industry.

Oriel and Ethyl

THE main speech at the Institution's dinner was made by Lord Tedder, who recalled the days when, as Director-General of Research and Development in the Air Ministry, he was flung into a very high-pressure, high-temperature

pot with I.C.I., Shell and Trinidad Leaseholds, in the hope that high octane fuel for the R.A.F. would result. Those were the days when he first made the acquaintance of many of the euphonious names which distinguished the petroleum industry—Oriel and Ethyl, Butyl and Methyl, and a lot of others. They got 100 octane and more, they got 120 plus octane, in no small measure due to Mr. Oriel. He regretted that he now found it impossible to appreciate what was afoot in science and technology, at a time when it was becoming more important to everyone to understand what was happening. He said that we needed first-class interpreters of scientific progress. Without them, insufficient students would take up science.

'Cold Sterilisation' at Cambridge

TWO members of the staff of the British Food Manufacturing Industries Research Association have been seconded to work at Cambridge with the D.S.I.R. team at the Low Temperature Research Station which is investigating the possibilities of sterilising foodstuffs by means of radiation—'cold sterilisation' as it is now commonly called in America. The director of this research association, Dr. F. H. Banfield, has rightly pointed out that these techniques of food preservation cannot be developed in a hurry, for it is always better to be 'sure rather than sorry' when dealing with matters of food technology. Of the experiments now in progress Dr. Banfield has wisely said, "A great deal will depend on the results obtained in the first year or so, and the medical aspect must be borne in mind in anticipating the extent to which practical use can be made of this new process."

U.S. Synthetic Rubber Expansion

PRESIDENT EISENHOWER has outlined plans for the expansion of the U.S. synthetic rubber industry. This will render America less dependent on natural rubber, but he added in his statement to Congress that natural rubber had a very definite place in the long-term growth of the country's rubber industry. During the last war one of the gravest strategic weaknesses of the U.S. fighting machine was rubber, and she still consumes the same quantity of the natural material as before the war. The President forecast that by 1960 total U.S. annual requirements would reach 1.7 million long tons and that by 1958 the country's synthetic capacity should reach this figure. He stated that three pilot plants were now in operation for the production of polyisoprene, the nearest synthetic in all its properties to natural rubber.

The Copyright Bill

THE Copyright Bill, which has received its third reading, will replace the Copyright Act of 1911. It makes considerable changes in the law. To assist 'research workers' and 'students' (and this is most important to all scientists and technologists), certain libraries, such as that of the Patent Office, are empowered to make and supply a copy of any article in any periodical, subject to certain safeguards; for example, no person can be given more than one copy of the same article, nor can he be supplied with a copy of more than one article in any one publication. The term 'periodical' is not defined, and may be open to wide interpretation. It may apply to a series of books of which the individual volumes are published periodically. In effect, the new provisions will give force of law to the Royal Society's Fair Copying Declaration, which many publishers have already signed. The new Bill allows the reproduction of copyright material for educational purposes by giving teachers and students the right to reproduce or adapt such material in the course of instruction. The reproduction or adaptation can be made provided it does not involve the use of a duplicating process, that is a process involving the use of an appliance for producing multiple copies.

CHEMICALS CAN MAKE NEWS

Sir: Why is it that industrial chemistry is paid scant attention in the National Press, as your editorial comment in *Digest* (May, 1956) pointed out? It is not because it is uninteresting or unimportant, or too complicated to explain. Nor is it because journalists are too bedazzled by rockets and atoms to think of anything else.

The basic trouble is that the industry as a whole spends a lot of money on advertising its products, but makes no comparable effort to explain to the public how they are made. There are a few enterprising firms to which this remark does not apply, but these are to be regarded as the exceptions which prove the rule. The general assumption seems to be either that the technicalities are too complicated to interest the public, or that they cannot be divulged without giving away trade secrets. Neither assumption is in fact true. Scientific journalists have managed to explain quite abstruse matters of atomic physics to the lay public, because various atomic scientists have taken the time and trouble to assist them to do so. Industrial chemists could do the same.

The basic problem is the attitude of mind. If the management of industrial chemical firms will attach real importance to establishing good "technological public relations," journalists and the public will be only too ready to respond—and the industry may find it is attracting more, and better, recruits.

Yours, etc.,
John Davy.

The Observer,
Tudor St., London, E.C.4.

Editor's Note: *John Davy is the Science Correspondent of "The Observer". A recent poll carried out among the correspondents of the national papers who specialise in scientific and technological matters has revealed that not more than one per cent. of the news stories and articles which they publish deal with chemical topics.*

Taming the Hydrogen Bomb Reaction

THE lecture given at Harwell by Academician Ivan Kurchatov takes the subject of thermo-nuclear reactions out of the sphere of complete conjecture to a stage comparable with that of atomic fission in 1939. He described experiments undertaken in the Soviet Union in an attempt to achieve the very high temperatures needed to bring about fusion.

Basically, the problem of harnessing thermo-nuclear reactions is that of generating extremely high temperatures of the same order as those which exist in the sun. The temperature must be sufficiently high to overcome the potential barrier which surrounds the nucleus. At any given temperature there is a certain probability that the nucleus will have acquired sufficient energy to emerge from the potential well in which it rests. Under these conditions two nuclei can react with one another, and in the lighter

elements the reaction may be such that the nuclei fuse and release energy.

The Russian experiments have been carried out in an apparatus related to the electronic flash tubes used by photographers. A very heavy current, of the order of a million amperes at a voltage of several kilovolts, is obtained by discharging a bank of condensers through a discharge tube filled with deuterium. Deuterium was chosen because fusion takes place at a lower temperature than for other substances.

When a current of this order of magnitude is passed through a gas the magnetic field set up is large, and as the current rises electrodynamic forces tend to constrict the discharge to a progressively narrower path. As contraction takes place the temperature in the waist of the discharge rises rapidly and values about a million degrees Centigrade were obtained.

As these temperatures are far higher than the vaporising temperature of all substances, it is essential that the hot gas be kept away from the walls of the tube. Whatever method is used for generation of the temperature, it is obvious that it can only be contained for a very short period of time without vaporising the apparatus. The pulsed discharge tube, which produces high temperatures for only a few micro-seconds, is thus a natural development, and has also been the subject of investigation in Britain and the United States.

The Hundred Biggest Companies

IMPERIAL CHEMICALS stands right at the top of the list of the hundred 'biggest' companies published by the National Institute of Economic and Social Research (2, Dean Trench St., London, S.W.1). There is no room here to give many of the interesting details which this fascinating document contains, but our table shows the assets and income for the twenty-five firms which head the list.

Company	£m. Assets	£m. Income	Income per £100 of assets £
I.C.I.	437.9	76.0	17.4
Unilever	246.1	48.7	19.9
Imp. Tobacco	170.5	31.2	18.3
Courtaulds	127.8	23.7	18.6
P. & O.	127.4	18.9	14.8
Distillers	110.5	20.1	18.2
Steel Co. of Wales	98.7	14.3	14.5
Vickers	96.9	12.1	12.7
Dunlop	88.6	17.8	20.1
Guest, Keen & Nettlefolds	83.9	16.3	19.4
Bowaters	67.4	11.0	16.3
Coats (J. & P.)	66.5	10.3	15.5
G.U.S.	64.5	19.0	29.5
A.E.I.	62.8	15.1	24.0
Ford	62.4	23.2	37.2
General Electric	59.6	10.2	17.1
Stewarts & Lloyds	59.3	15.0	25.3
United Steel	56.8	11.3	20.0
Br. Motor Corp.	56.3	21.2	37.6
Turner & Newall	52.7	15.7	29.9
Tube Invest.	50.3	8.0	15.9
Marks & Spencer	50.0	10.3	20.6
Cunard	49.2	7.3	14.8
B.I.C.C.	47.0	7.4	15.7
Woolworth	46.3	21.3	46.0

The income column gives 1954-55 figures, and the assets are given 'at book value.' Depreciation is, of course, taken into account when arriving at asset figures, and therefore these will tend to be lower for an old established company than for a company of comparable manufacturing capacity whose buildings and plant are new. This should be borne in mind when considering the table. It is probably one of the main reasons why Stewarts and Lloyds, for example, make more profit on £60 million of assets than the Steel Company of Wales on £99 million.

Three companies in the chemical and allied fields are listed as having assets of over £25 million, and another 31 firms top the £2¼ million figure. The corresponding figures for iron and steel companies are 7 and 43 respectively.

A Reactor Cooled with Diphenyl

AN experimental reactor is to be built in the United States this year which will test the use of diphenyl, a hydrocarbon obtained from petroleum, as a moderator and coolant material. Studies made by the U.S. Atomic Energy Commission indicate that it offers several potential advantages, including low corrosion of fuel elements, and a high boiling point which makes reasonably high temperatures possible. Diphenyl and similar organic compounds are used quite commonly in some chemical processes as a heat transfer agent.

This new reactor—part of the A.E.C.'s civilian power reactor development programme—will be built and operated by a private firm, Atomics International, at the national testing station in Idaho.

Polythene Film

THE uses of polythene in the chemical industry are well brought out in the film *Alkathene: The Adventurous Years*, made for I.C.I. by the Film Producers Guild. There was, for example, one excellent sequence showing the laying of a large polythene drain at the Billingham sulphuric acid plant, and the film includes some interesting shots taken in the factory of the Chemical Pipe and Vessel Co. Ltd. and covering the fabrication of various items in this plastic. At the press show we sat next to a professional film critic who thought the film was too much like a manufacturer's catalogue. We were inclined to agree with his verdict. Although the film was designed primarily for technical audiences, it should have been possible to allow the film director greater scope to exercise his cinematic talents.

Pullman have concluded an agreement with Phillips Petroleum which will enable them to manufacture polythene by their catalytic process. This is capable of producing not only polythene but also copolymer mixtures of olefins. The synthesis of polypropylene is possible by a recently patented variation of the original low-pressure process. The development of a whole range of resins based upon poly-olefins may be expected in addition to the new type of polythene. This product, like Alkathene HD, can be heated to sterilisation temperatures without deformation. It has other valuable properties; for example, its ultimate and impact strength and rigidity are superior to that of polythene derived from conventional high-pressure processes.

Chelated Toothache

THE traditional mixture of zinc oxide and eugenol, which forms the white 'putty' that dentists use for stopping deep cavities in teeth, has long been a mystery to chemists. No one could be sure whether the reaction between the two materials was a true chemical reaction or just a physical process like hydration. Now it has been established by four scientists working at the U.S. Bureau of Standards that a chelate compound, zinc eugenolate, is formed. As readers know, chelate compounds are cyclic compounds which are formed by a co-ordination process, in this case with a zinc atom. Most chelates are remarkably stable. In the case of zinc oxide and eugenol, long, thin crystals are formed. The crystals act as a matrix for the set mass and absorb any unreacted material. The reaction is thus both a chemical and a physical process.

Now that the scientists understand the mechanism that causes this dental 'putty' to set, it should not be long before they will be able accurately to control such matters as setting time, hardness and the strength of the hardened product. The result should be better fillings and less toothache.

Victoria Instruments

DEWPOINTMETER

Developed by British Coal Utilisation Research Association

SPECIFICATION:

The instrument consists essentially of a high quality Pyrex glass detector element bearing 2 Pt / Pt 13% Rh thermocouples in the hemispherical surface, and mounted on a probe 1 inch in diameter and 6 ft. long. Cooling air and compensating leads from the other end of the probe connect to a box (24 in. x 10 in. x 6 in.) of good quality hardwood fitted with Rototherm, double range voltmeter and millivoltmeter and a 5 range microammeter. 'All these instruments are first grade accuracy (B.S.S. 89) having spring mounted movements and are built into a single unit which is internally earthed.

Cooling air connections are of the "Instantair" type and all metal parts are chromium plated. Calibrations can be made in English or Metric units.

Overall weight—

Probe and leads	...	8 lb. (4 Kg.)
Box	...	30 lb. (14 Kg.)

BRIEFLY, the Instrument:

The probe is inserted into the gases under test and the detector element temperature is controlled by the admission of cooling air from some suitable source (e.g. a small compressor) to its underside. The two thermocouples measure this temperature. When the surface is cooled below the dewpoint of gases they also become the electrodes of a "cell", the conductivity of which is recorded on the microammeter.

The detector element is constructed in such a way that its temperature can be controlled at fixed temperatures below the dewpoint for long periods, and comparative measures of the amounts of sulphuric acid condensed out at any selected temperature can be made.

The instrument is of particular value in determining the temperature range over which corrosion by sulphuric acid may be expected.

Sole Manufacturers:

VICTORIA INSTRUMENTS

Proprietors: V.I.C. (Bournemouth) Ltd.

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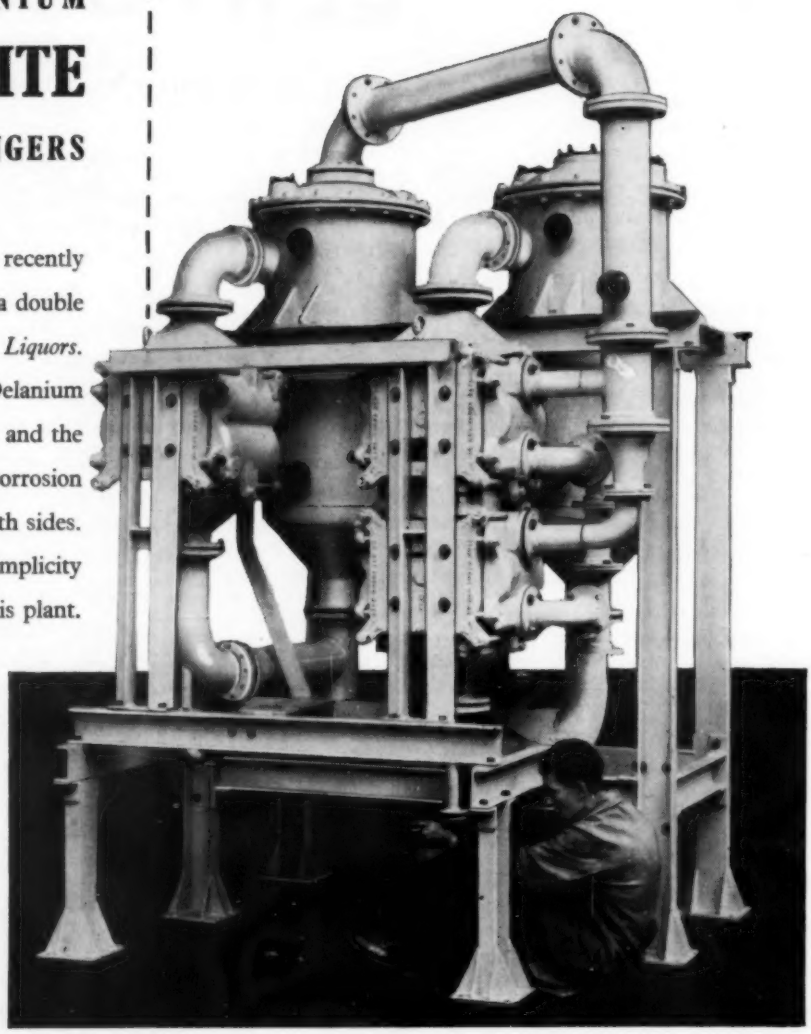

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BRITISH CHEMICAL ENGINEERING
A HEYWOOD TECHNICAL PUBLICATION

Chemicals on the Farm

THE potato shortage has made headline news, and not surprisingly, since housewives have been forced to pay sixpence a pound for poor quality old potatoes and over a shilling for indifferent new potatoes. The incident has had the salutary effect of reminding the country of a few home truths about agricultural production which were in danger of being forgotten. The acreage under potatoes has been dwindling steadily since the war, and last year the crop could have only just been adequate if it had been a perfect growing season. As it was, drought reduced the yield considerably, the farmers harvesting only 7.3 tons an acre on the average as against the normal yield of just under 8 tons. One point that ought to be noted about the troublesome deficit is that it would have been a major disaster had the yield per acre been at the pre-war level. Then the farmer obtained only 6½ tons of potatoes per acre. The extra ton and a half which he now regularly harvests results mainly from the much heavier dressings of artificial fertilisers he applies to the land.

Britain's best farmers now manure most crops for maximum yield, and that would be impossible of attainment without an abundance of factory-made fertilisers. These and other farm chemicals which the chemist and the chemical engineer have brought into production have revolutionised agriculture. Almost obsolete today is the traditional four-course rotation involving swedes, barley, hay and wheat, and involving too a considerable dependence upon imported feeding stuffs for the cattle required to complete the "cycle". The modern rotation of potatoes, barley, peas and wheat (all of which are sold off the farm except the straw) has replaced it, but with this system the fertility of the land can be maintained only if the losses of plant nutrients are made good by artificials. With this rotation the farmer should put back about 400 lb. nitrogen, 128 lb. phosphorus pentoxide, and 435 lb. of potash per acre during the four-year period. The average farmer cuts down on those figures, and relative to several European countries our land is undermanured. The Dutch farmer, for example, uses four times as much nitrogen per acre.

British farms could profitably use more, and we welcome the plans to boost British production of fertilisers considerably. At this stage the farmers can consume all the ammonia which can be produced. Wherever reasonably pure nitrogen or reasonably pure hydrogen is available in large quantities as a by-product, consideration should be given to the possibility of starting an ammonium synthesis plant. Thus a steel works which switches over from coal to oil-firing has a surplus of coke oven gas that is rich in hydrogen. If the same works has a gas separation plant which provides bulk oxygen for use in the steel-making process, then plenty of nitrogen will be available to support a unit producing ammonia. The by-product hydrogen from a petroleum refinery can similarly be harnessed for the benefit of the farmer; an example of what can be done is the ammonia plant to be built at Shell Haven which will link up with the new Fisons fertiliser factory at Stanford le Hope.

For a long time to come the mainstay of the British farmer will be ammonium sulphate. But our agricultural scientists are busy testing out the use of ammonia, both anhydrous and in solution, as a straight fertiliser, a practice which is already established in the U.S.A. Its use helps to conserve supplies of sulphur, and the same thing is true of such fertilisers as ammonium nitrate, nitrophosphates and calcium nitrate. As Sir William Ogg of Rothamsted said recently, we can expect the production of nitrogen and phosphorus fertilisers to be linked together more closely, and that trend would provide plenty of exercise for our country's chemical engineering talent.

For potash supplies, we rely on imports. Both I.C.I. and Fisons have decided against the immediate exploitation of the vast potash deposits in Yorkshire. But the time will come when methods of working these deep deposits will need to be perfected, and in due course our chemical engineers will have some fascinating problems to solve.

The chemist and the engineer have added much to the fertility of the soil of the western world. There is enormous scope for their talents in countries like India where many more factories such as the ammonium sulphate plant at Sindra need to be built. The world as a whole can consume at least twice as much nitrogeneous fertiliser as the factories turn out today.

While farmers all over the world need to aim at maximising crop production, they also need to minimise the losses which weeds, crop diseases and insect attack cause. That very important aspect of good scientific husbandry will be discussed at the second international conference on crop protection being held at Fernhurst this month. In this sphere the biologist and the chemist have to work as close allies, and then the engineer comes in to organise the production of the new insecticides, fungicides and weedkillers which they perfect. Progress since 1939 has been most spectacular. DDT, BHC, the organo-phosphorus insecticides, chlorfensone, aldrin, dieldrin, endrin: all these have come on the market since 1939, and they have altered the balance of nature strongly in man's favour. Only the eelworm remains more or less completely beyond the reach of man's ingenuity. Losses due to fungi have been checked enormously, though the experts are not likely to rest on their laurels until they are able to supply fungicides that can be handled with greater safety. The selective weedkillers represent another wonderful advance. In Britain their use on cereal crops has added nearly half-a-million tons of grain to the nation's granary. Other synthetic plant hormones are being exploited for different purposes.

Food production has been revolutionised by factory-produced fertilisers, and now plant protection is being revolutionised by other products of the chemical industry. Dr. E. Holmes has said that the use of the latter compounds is likely to be doubled in Britain in five to ten years. For the world as a whole their use is likely to increase by a very much larger factor—perhaps ten times—in the same period, and that means big export markets and plenty of room for expanding production in Britain.

A Guide to the Selection of Continuous Centrifuges

M. E. O'KEEFFE TROWBRIDGE, B.Sc., A.C.G.I., A.M.I.Chem.E.

THE various types of centrifuges may be classified initially according to the nature of the centrifugal action involved in the separation. Thus one has the two main groups of centrifuges classified as "Centrifugal Filter" or "Centrifugal Sedimentor", as well as types in which both modes of action are taking place (see Table I). In the true centrifugal sedimentor the solid moves radially under centrifugal force relative to the continuous phase, and it is essential that a density differential should exist between the two liquids, or between the solid and liquid, to be separated. In the case of the centrifugal filter, however, the liquid moves radially under the action of centrifugal force through a bed of the solid, which is generally maintained by some form of perforated supporting media and no density difference is necessary.

The Super Centrifuge

This is a tubular bowl type centrifuge (Fig. 1), designed to combine simplicity of bowl design and a minimum number of moving parts with the application of a very high centrifugal force to the material being treated. The ratio of bowl length to bowl diameter ranges from 4-8 and bowl speeds vary from 15,000-50,000 r.p.m. These speeds correspond to a centrifugal force of from 12,000 times the force of gravity, up to 65,000 times gravity, which is considerably greater than that developed in the other types of continuous industrial centrifuge.

The tubular bowl centrifuge is ideally suited to the separation of two immiscible liquids, and to clarification applications where the quantity of solid phase is less than, say, 1%, and where the particle size of the solids is small enough to warrant the use of the high centrifugal force. Examples of such applications are the clarification of varnish, the continuous purification of lubricating oil, clarification of cider and fruit juices, and multitudinous other operations in the chemical and process industries.

Another operation which can be successfully carried out on the tubular bowl centrifuge is that of classification, since a sharp cut-off is obtained between oversize and undersize particles. Lacquers, enamels, dye-pastes, pigmented latex, and similar substances can be treated in the centrifuge to remove oversize particles and agglomerates of particles.

Apart from the low cost of the machine per unit of throughput, its ease of operation and maintenance, etc., the tubular bowl centrifuge is widely applicable in the chemical industry due to its versatility, and the fact that its simple construction permits fabrication in corrosion resistant materials. In many plants producing small annual tonnages of a variety of materials, one machine is used for a number of different operations, depending on the chemical in current production.

The tubular bowl centrifuge can also be used as a "polishing" machine for removing small quantities of solids from the liquid effluent from one of the other types of centrifuges, such as the solid bowl scroll discharge type, described below. These large continuous machines serve to remove the bulk of coarse particles, whilst the tubular bowl centrifuge is used to remove the traces remaining. The advantages of such a system are that each machine is operating on the range of particle sizes most suited to its characteristics.

Liquid discharge from the tubular bowl centrifuge is continuous. The solids remain in the bowl and have to be periodically removed as a bowl cake. This operation of periodically cleaning the bowl, however, only occupies approximately 15 minutes, and can in fact be carried out in 5 minutes if two bowls are used, one being cleaned, while the other is being used.

Apart from applications in the processing of chemicals, another interesting example of the use of the tubular bowl centrifuge is in the dehydration and purification of various types of oils. Almost every type of oil used in industry is subjected to some form of contamination during its life, and unless removed this contamination sets a limit to the useful life of the oil. Steam turbine lubricating oil becomes contaminated with water from leaking glands, by rust from the oil reservoir and oilways, and by polymerisation and oxidation products of the oil itself. Diesel engine lubricating oil becomes contaminated by carbon and other products of combustion of the fuel which tends to destroy its lubricity. Transformer and switch insulating oil loses its dielectric strength due to moisture, to sludge, and to colloidal carbon formed by arcing. Cutting oil gathers metallic particles which impair its efficiency, etc., etc.

These impurities which enter the oils occur as discrete particles or phases of density different from the oil itself. The solids are generally present, moreover, in small proportions, but their effect on the oil is important. It follows, therefore, that a centrifuge is the ideal machine for the continuous purification of oils of this type both on process considerations as well as on practical grounds due to the simplicity and robustness of design of the machine.

1 *Cutaway view of tubular bowl type centrifuge.*
2 *The batch bowl disc type centrifuge.*
3 *Disc type centrifuge as used in the Dairy Industry.*
4 *Cross-section of a recycle type nozzle discharge centrifuge.*
5 *The valve nozzle type centrifuge.*
6 *The self-opening type centrifuge.*
7 *Cutaway view of solid bowl scroll discharge centrifuge—conical bowl type.*
8 *Cutaway view of solid bowl scroll discharge centrifuge—cylindrical bowl type.*

Disc Type Centrifuges

In an attempt to reduce the distance through which a particle has to settle, plates or baffles may be introduced into the centrifuge bowl. This gives the so-called "disc-type centrifuge" (Fig. 2). Whilst these discs could in theory be introduced into a tubular bowl centrifuge, in practice in the disc-type centrifuge the height of the bowl is reduced as the diameter is increased, and the speed and centrifugal force is greatly reduced. In consequence, whilst the direction of flow of the fluid in a tubular bowl centrifuge is generally parallel to the axis of rotation of the bowl, in a disc-type centrifuge the liquid is flowing inwards at an angle of 35°-45° to the axis of rotation, to a smaller diameter. The solid particles on the other hand proceed outward in an approximately radial direction, until they strike the underside of a disc.

Depending on the nature of the particles and the angle of the discs, these particles either collect on this under-surface, or else slide outwards down the underside of the discs in a thin layer. When they leave the disc stack they either flow to the wall of the bowl where they collect, or else they are re-entrained by the liquid passing up into the disc stack. The phenomena of re-entraintment causes disc centrifuges to be, in fact, much less efficient than would appear from a simple calculation of separational

efficiencies based on centrifugal force and settling distance. This, combined with the high capital cost of batch disc centrifuges as compared with an equivalent tubular bowl machine, the maintenance cost, mechanical complexity, and difficulty of cleaning, accounts for the fact that their use is generally less favoured in the chemical and process industries. Modifications to the disc principle, however, do permit the solids to be continuously discharged, and it is in this function, rather than its use as a "batch" type centrifuge, that the disc machine finds its best field of application in these industries.

A good example of the use of the batch disc-type centrifuge is in the dairy industry. The process of cream separation is one of concentration of a discontinuous light liquid phase, which tends to resist agglomeration. For such a process a disc type machine is to be favoured due to the stratifying effect of the disc. Disc centrifuges of this type are available with capacities of up to 6 tons per hour of whole milk, to yield as a heavy phase discharge milk at less than 0.01% butter fat content (Fig. 3). By means of external back pressure control the butter fat content of the light phase cream can be varied at will. Such machines are generally constructed with all contact parts of stainless steel, and are totally enclosed for hygienic reasons. Particular attention is paid in the design to avoid stagnant corners, and the whole is arranged for easy cleaning to avoid pockets of bacterial activity.

Nozzle Discharge Type

Where continuous solid discharge is required, the low length to diameter ratio of the disc centrifuge lends itself to the provision of orifices in the periphery of the bowl through which the solids can be discharged. As may be seen from Fig. 4, the bowl shell is modified so that the solids deposited are guided down towards the nozzles. The angle of this bowl wall has to be sufficiently steep so that the solids will flow down. If too shallow an angle is used, for solids having a high angle of repose, small mounds will build up until the solid itself provides an appropriate angle. This in itself is not harmful, but the danger exists in such a case that the solids will build back into the disc stack, thus causing a serious loss of efficiency due to blanking off part of the stack.

In a similar manner solids will build up in between nozzles to form their own angle of repose. For a given

Table 1 — Classification of Continuous Centrifuge Types

Mechanism of Primary Separation	Bowl Type	Method of Solids Discharge	Speed Range R.P.M.	Machine Type	Applications (Minor applications in brackets)	Notes
CENTRIFUGAL SEDIMENTOR	Tubular Bowl	Batch-Manual	15,000-50,000	Super-Centrifuge	A.B.C.G. (E)	Very dry and compacted solid produced due to high centrifugal force
	Disc Bowl	Batch-Manual	4,000-7,000	Batch disc-bowl centrifuge	A.B. (C)	Especially suited to concentration of light phase emulsions
		Continuous-Nozzle or Recycle Nozzle	4,000-7,000	Nozzle discharge centrifuge	B.C.D.G. (E)	Solids discharged as pumpable slurry
		Continuous-Valve controlled Nozzle- Automatic	4,000-7,000	Automatic valve-nozzle centrifuge	B.C.D.E.	Produces very high solids concentration
		Continuous-Valve controlled Nozzle-Externally operated	4,000-7,000	Valve-nozzle centrifuge	B.C. (D) (E)	Produces very high solids concentration
		Intermittent Annual Ring Valve-Externally operated	4,000-7,000	Self-Opening Centrifuge	B.C.	Principally used for treatment of heavy fuel oil
	Solid Bowl	Intermittent By Knife or Skimmer Pipe	500-2,000	Skimmer Type Centrifuge	E.	May be operated either by batch or continuous filling
		Continuous-By Scroll	500 4,000	Cylindrical Scroll Discharge Solid Bowl Centrifuge	E.G. (C) (D)	Excellent for amorphous and microcrystalline material
COMBINED CENTRIFUGAL FILTER AND SEDIMENTOR	Solid Bowl	Continuous-By Scroll	500-4,000	Conical Scroll Discharge Solid Bowl Centrifuge	E.G. (C) (D) (F)	Reasonable degree of washing obtained with free draining crystals
CENTRIFUGAL FILTER	Perforated Basket	Batch Continuous-By Automatically operated knife	500-2,000	Automatic Knife Discharge Centrifuge	F.E.	Washing Excellent—permits wide flexibility in operation. Suitable for all sizes of crystals
		Continuous-By Reciprocating piston	500 2,000	Pusher Centrifuge	F.	May be used for coarse crystals
		Continuous-By Scroll	500 2,000	Perforated Basket Scroll Discharge Centrifuge	F.	Made in variations with both conical and cylindrical baskets
		Continuous-Self Discharging	1,000 3,000	Self Discharging Crystal Centrifuge	F. (Coarse crystals only)	Only suitable for coarse crystals

KEY TO APPLICATIONS (Column 6 above)

(A) Separation of two immiscible liquids, in the absence of solids.
e.g.: *separation of water from oil.*

(B) Separation of two immiscible liquids, with the simultaneous removal of suspended solids.
e.g.: *dehydration of C.W.G. tar.*

(C) Clarification of a liquid or mixture of liquids (i.e.: the separation and recovery of solid particles that are dispersed in a liquid).
e.g.: *clarification of fruit juices; vegetable oil refining; recovery of theobromine.*

(D) Thickening of a slurry. (i.e.: the concentration of the solid phase.)
e.g.: *thickening of starch and gluten; manufacture of clay.*

(E) Recovery of amorphous, or fine crystalline materials, from a slurry; possibly combined with the washing of solids separated.
e.g.: *manufacture of plasterboard; recovery of fish meal, or whale meal from press liquor; dewatering of coal washing plant tailings; manufacture of all types of fine crystaline materials.*

(F) Recovery, Washing and Drying of free draining crystals.
e.g.: *manufacture of all types of coarse crystalline materials, ammonium sulphate, sodium chloride.*

(G) Classification of solids according to particle size (i.e.: the removal of oversize or undersize particles).
e.g.: *manufacture of paint and other pigmented products; manufacture of grinding abrasives; titanium dioxide; starch manufacture; production of paper coating clays.*

(H) Combinations of two or more of the above operations.

angle of repose the height of such accumulations of solids will depend on the distance between adjacent nozzles and, for a given bowl diameter, on the number of nozzles. Thus, in order to avoid the apex of such accumulation from penetrating the disc stack, one has to regulate the number of nozzles according to the nature of the solids. In general, the use of from 4 to 12 nozzles is found to be desirable for most of the types of solids handled on this class of centrifuge. The pressure of fluid at the nozzles is relatively high, being of the order of 1,000 lb./sq. in. In consequence, to avoid excessive liquid flow through these nozzles, they must be of small diameter. For operation at capacities of 1,000-10,000 gallons per hour feed to the centrifuge, the nozzles used range from 0.030 in. to 0.070 in.

In order to recover some of the energy lost in the liquid leaving the nozzles, and thus to reduce the power requirements of the unit, it is usual to arrange these nozzles to point tangentially backwards operating on the principle of the reaction turbine.

The Recycle Nozzle Type (Fig. 4). In many cases, it is desired to obtain a high ratio of concentration of the inlet slurry to that of the material discharged through the nozzles. The maximum feed rate to the centrifuge is limited by the separating capacity of the disc stack, in order to obtain an acceptable clarity of product, and hence, on material balance considerations it will be readily seen that to obtain this high concentration ratio it is necessary to restrict the flow of nozzle discharge from the centrifuge. This may be achieved by decreasing the number of the nozzles, and by decreasing the diameter of the nozzles. However, as pointed out above, for a given material, if the number of nozzles is reduced below a certain critical value, the apex of the accumulation of solids between the nozzles will build back into the disc stack causing a loss in separational efficiency. Similarly, if the diameter of the nozzles is reduced the tendency to blockage will increase and rough operation will result.

One solution to the problem of obtaining a higher concentration of solids in the nozzle discharge, without reducing the number or diameter of the nozzles to an unacceptable figure, is to artificially increase the mean concentration of solids in the slurry fed to the centrifuge. Thus, whilst maintaining the same concentration ratio, the concentration of the nozzle discharge will be increased. This may be done by simply taking some of the nozzle discharge and continuously blending it with the feed to the machine, and in some cases this is in fact done. A disadvantage of this method, however, is that solids which have already been separated in their first passage through the bowl have to be separated once again, and this may cause a fall off in product clarity, or a loss of throughput capacity. Moreover, the increased fluid rate in the inlet section to the disc stack results in increased turbulence, and a loss of efficiency. To overcome this a recycle bowl may be used. This is designed so that part of the nozzle discharge can be returned to the bowl, to discharge at a point adjacent to each nozzle. In this way an artificially high concentration of solids is built up adjacent to the nozzle, and the discharge capacity of the nozzles is satisfied, whilst still maintaining the net discharge of nozzle liquor from the system at a sufficiently low rate that the desired over-all concentration ratio may be obtained.

Whilst this principle of recycling has a wide applicability, with some solids which form light agglomerates it cannot be used since the force of discharge from the nozzles is sufficient to break down the agglomerates. In consequence, a material which would separate well on its first passage through the centrifuge would not separate if recycled to the bowl, and a fall off in liquid clarity would be observed.

As with the tubular bowl and batch disc centrifuges, the nozzle and recycle nozzle type machines are widely used for separation, clarification and classification operations—especially in cases where the high concentration of solids would result in too frequent cleaning being necessary in the former types of machines. An excellent example of the field of application of the nozzle type centrifuge is in the manufacture of corn starch by the wet process. This process gives examples of the nozzle and the recycle nozzle machine being used as a concentrator as well as a classifier.

Starch occurs in nature together with insoluble protein from which it has to be separated. The basis of the wet starch process in that starch settles more readily than does the insoluble protein. In early processes this separation was carried out on gravity settling tables, but more recently centrifuges of the nozzle type have been used for carrying out this classification process centrifugally. In this case the starch is discharged as a slurry through the nozzles of the centrifuge, whilst the gluten overflows as the light phase. This centrifugal fractionation according to particle size and density may be carried out in more than one stage, and a great deal of the success of starch processing depends on the efficiency of this classification step.

Apart from the fractionation, centrifuges used as concentrators are used in other parts of the process for preparing the mill starch for fractionation, and for working up the starch flow and the gluten flow. In fact, in a fully modernised starch house, nozzle type centrifuges are used in as many as seven different stages in the process.

The Valve Nozzle Type

Due to the possibility, referred to above, of breakdown of agglomerates during discharge from the nozzles, and the limitation of ultimate concentration of nozzle discharge imposed by the characteristics of the recycle system, the use of the recycle nozzle type centrifuge has definite limitations in its field of use. To overcome some of these objections a different approach has, in recent years, been made to the problem. To restrict nozzle discharge, instead of reducing the diameter or number of the nozzles, a control is applied on the time for which the nozzles are open, by building valves into each nozzle (Fig. 5). This permits very high concentration ratios to be achieved, even with the slurries consisting of relatively fragile agglomerates. It also enables a higher nozzle discharge concentration to be worked with than would be possible with a recycle bowl.

Two types of valves are commonly used. In both types, each nozzle has a separate valve. In the case of the automatic valve type centrifuge, the depth of solids deposited in the bowl controls the opening and closing of the valves, by means of a hydraulic self-operating mechanism in the valve itself. The centrifuge can thus automatically compensate for variations in feed rate and concentrations of solids in the feed, and still deliver a sludge of constant composition. The operation of this type of valve is, however, somewhat sensitive to the type of solids being separated, and for this reason its field of application is limited.

The valves in the externally actuated valve type centrifuge, however, are positively operated by an hydraulic control mechanism. This mechanism, which is mounted outside the centrifuge, can be time-cycle, manual, or operated by means of a photoelectric cell operating on the clarity of the liquid phase effluent. The frequency and duration of the opening of the valves can thus be controlled to discharge very high concentrations of sludge from the nozzles and, in fact as a result of this degree of control of nozzle discharge, the valve nozzle type centrifuge can be operated to produce the highest concentration of discharge

obtainable with centrifuges operating on the disc principle. The only limitation on the machine is that, since there is less liquid discharge to flush the solids through the nozzles, as the desired concentration increases, so the nature of the solids becomes increasingly important.

Apart from the use of the valve nozzle type centrifuge for a single stage concentration of solids, it may be advantageously used where reslurry washing of the nozzle discharge is required. Due to the higher concentration of solids obtainable from the valve nozzle type as compared with the ordinary nozzle type, a much better degree of multiple stage washing can be obtained. In one case, for example, a two - stage installation of valve nozzle centrifuges, with reslurry washing between stages, gave the same washing efficiency as three stage operation of ordinary nozzle type centrifuges. In addition, the solids from the second stage valve nozzle machine were considerably dryer than the solids discharged from the third stage plain nozzle unit, and thus subsequent drying costs were substantially reduced.

The Self-opening Centrifuge

An interesting alternative approach to the problem of controlled solids discharge is exemplified by the self-opening type centrifuge (Fig. 6). In this case, instead of employing valve controlled nozzles, the solids discharge is regulated by means of an annular ring valve. This type of unit is designed to give constant high separating efficiency comparable to that given by centrifuges using the disc type bowl, but having the facility of discharging the solids intermittently as required without the machine being stopped.

The bowl of the machine is constructed with a conical sludge space, the angle of which ensures complete discharge of all solid matter. It is designed for long running periods, having a sludge space of the largest possible volume and is opened and shut hydraulically. The method of operation ensures that the sludge discharged contains the minimum quantity of liquid. Only a small amount of fresh water is required to operate the hydraulic system, the operation of which is simple and is by means of a single valve. The principal field of operation of this type of centrifuge appears to be in the purification of heavy fuel oil for use in diesel engines.

The Skimmer Type Centrifuge

The skimmer of this unit comprises an imperforate bowl rotating about a horizontal axis. Models are made with an overhung basket having double bearings mounted at one end of the centrifuge, or alternatively larger types having a shaft mounted on bearings arranged at both sides of the basket.

In the first variation of this type of centrifuge, the bowl is filled batchwise and the unit run to allow the solids to sediment to the walls. The supernatant liquid is removed by means of a skimmer pipe, after which the solids are discharged by a knife mechanism.

An alternative arrangement allows the slurry to be fed continuously over a guide distributor at the back of the bowl. Sedimentation takes place continuously in the bowl and the settled liquor overflows over the lip ring at the front of the bowl. To operate in this manner requires a material having a much higher sedimentation rate than with the batch sedimentation method.

In applications where the solids content of the feed slurry is very low, operation may be continued for several hours before the necessity arises for removing solids from the bowl. The liquid throughput capacity varies with the sedimentation characteristics of the solids present, but is of the order of up to twenty-five times the capacity of the bowl. Centrifuges of this type can be built in which the bowl is divided into chambers so that liquid/liquid separation can be effected, as well as solids separation.

Solid Bowl Scroll Discharge Type

In the solid bowl scroll discharge, or "decanter" type of continuous centrifuge, a combination of centrifugal settling and centrifugal filtration is taking place. The decanter type consists of a cylindrical or conical solid bowl rotating about a horizontal axis between two fixed bearings. Inside the bowl and rotating about the same axis is a helical scroll conveyor which, however, rotates at a differential speed as compared with the bowl. This speed differential is achieved by means of an epicyclic gearbox operating between the bowl and the conveyor drive. A centrifugal separating force of up to approximately 3,000 times the force of gravity is generated in the bowl of the centrifuge.

The slurry to be separated is fed to the inside of the bowl. The centrifugal force deposits solids on the bowl wall. These are moved up the bowl by means of the scroll conveyor and are discharged through circumferential ports at one end of the bowl. The clarified liquid passes to the other end of the bowl, and is discharged over an adjustable weir which regulates the depth of the "pond" in the bowl, thus controlling the liquid residence time and thereby the degree of clarification obtained.

In the conical bowl version (Fig. 7), the solids are moved up the bowl, and pass across a dry section above the liquid level, known as a "beach", before being discharged. In this section of the bowl the liquid trapped in the solids is given the opportunity to drain away.

In the cylindrical bowl version (Fig. 8), the solids move to the solids discharge end of the bowl below the liquid level, and extrusion plays a part in the mechanism of discharge.

The conical type decanter is to be favoured where the solids separated are fairly firm, and where dryness of the solids rather than liquor clarity is of primary importance. However, for plastic solids and in case where good liquid clarity is essential, the cylindrical decanter is preferred.

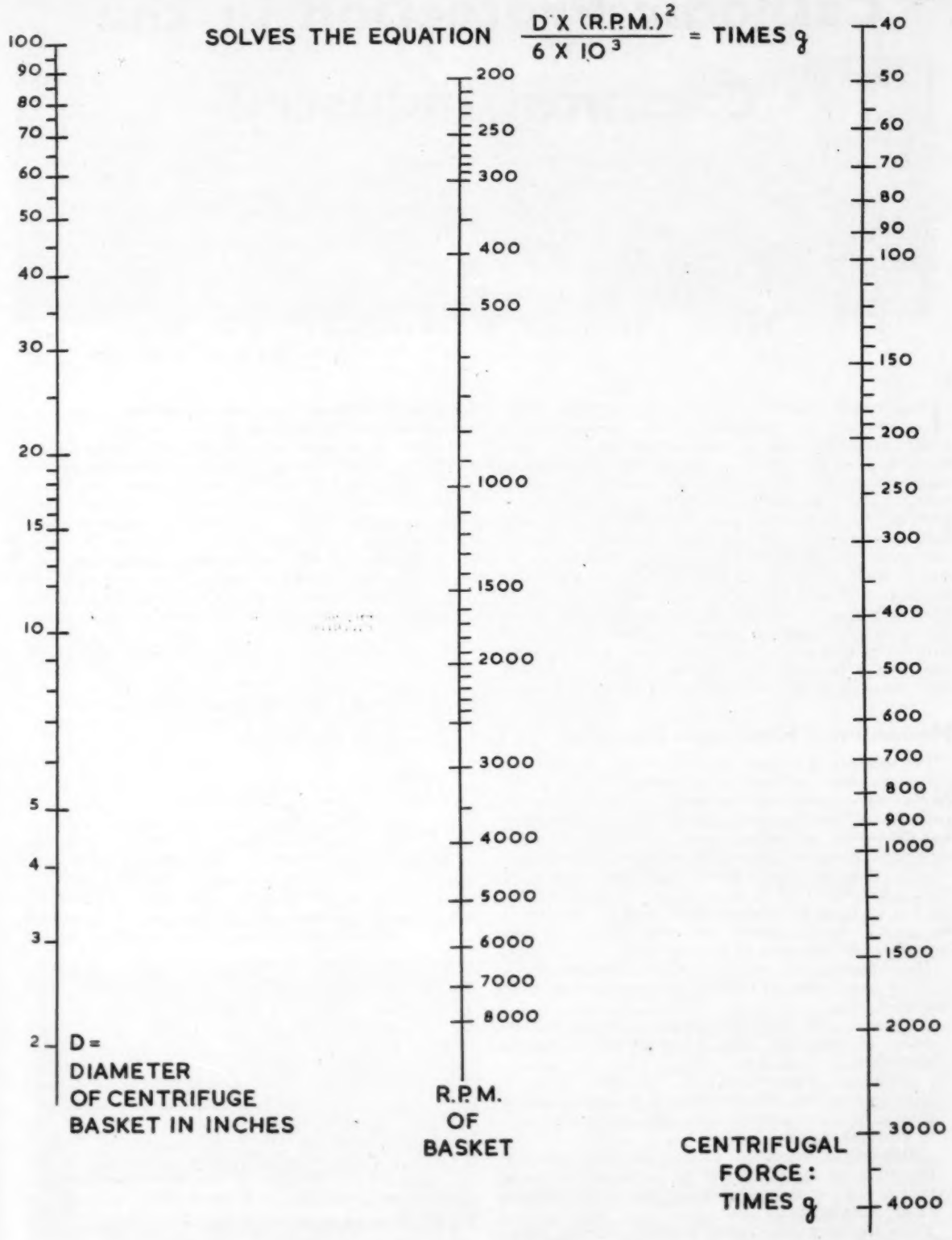
In both types, the decanter can either be used as a clarifier to remove all the solids, or as a centrifugal classifier to discharge large particles as a solid phase, whilst allowing fine particles to remain in suspension. By careful selection of throughput and operating conditions a reasonably good "cut" can be obtained at the desired particle size. By using a special design of double feed tube, wash liquor can be deposited on the solids beach and a degree of displacement wash thus effected. This is not as thorough as that obtained in a perforated basket type machine and, in addition, the wash liquor mixes with the mother liquor and discharges with it. Where a high degree of washing efficiency of the product is required, or where the wash liquor must not mix with the mother liquor, it is usual to employ a reslurry technique, using two stages of centrifugal decanters.

In many cases the decanter is used as a "roughing" centrifuge for separating the coarse and relatively easily removed solids before feeding the liquor to one of the other types of machines, such as a tubular bowl centrifuge or one of the nozzle type centrifuges, for "polishing". In the case of the tubular bowl centrifuge, this preliminary solid removal stage reduces the frequency of bowl cleaning necessary. The use of the decanter before a nozzle machine is frequently useful to remove coarse solids which would either not discharge from the nozzles, or would cause severe and frequent blockage of the nozzles.

All illustrations except Fig. 6 are reproduced by courtesy of Sharples Centrifuges Ltd. Fig. 6 was provided by Alfa Laval Co. Ltd.

The next issue of BRITISH CHEMICAL ENGINEERING will feature an article by the same author dealing with the subject of Centrifugal Filters.

SOLVES THE EQUATION $\frac{D \times (R.P.M.)^2}{6 \times 10^3} = \text{TIMES } g$



Cathodic Protection in the Chemical Industry

Increasing use is being made of this technique for stopping corrosion of tanks and pipelines. This article describes the basic principle of this system, and its applications to chemical equipment

by F. A. TRACY, B.Sc., and P. W. HESELGRAVE, B.Sc., D.I.C.*

THE method of combating electrolytic corrosion, which is known as cathodic protection, has been successfully applied to a wide range of structures and plant in recent years. Here, we are not concerned with the various natural mechanisms, such as film formation and hydrogen overvoltage—which prevent the corrosion of a metal in a given electrolyte—but with a specific method of preventing such corrosion when it would otherwise occur. It must be understood that unless the metal to be protected is in contact with an electrolyte, cathodic protection cannot be employed. Further, although theoretically the method could be applied to a wide range of metals and plant, its use in practice is limited mainly to the protection of ferrous metals in neutral, and near neutral aqueous solutions; it has, however, been applied to the protection of both aluminium vessels and buried lead sheathed cables.

Mechanism of Electrolytic Corrosion

The tendency of a piece of metal to lose positive ions to an electrolyte in which it is immersed results in the parent body acquiring a negative charge; the equilibrium potential established depends upon the nature of the metal and the nature and concentration of ions present in the electrolyte. When two parts of the surface of a continuous metallic structure have different equilibrium potentials, there is a resultant e.m.f., equal to the difference between the two interface potentials, tending to cause the flow of an electric current round the path formed by the electrolyte and the metal of the structure.

The differences in potential at the metal/electrolyte interface may arise by several mechanisms, the most important being:

Galvanic: the corroding system is formed by two pieces of dissimilar metal immersed in a common electrolyte.

Differential Oxygenation: the corroding metal is homogeneous, but different parts of its surface are in contact with an electrolyte containing varying amounts of dissolved oxygen.

Differential concentration: the corroding metal is homogeneous, but different parts of its surface are in contact with an electrolyte containing varying amounts of dissolved salts.

There are many other means by which differing potentials may be developed, but these, in themselves, are not widespread causes of corrosion in chemical plant.

The part of the structure with the greater (more negative) open circuit potential at the interface is the anode of the corroding cell; over this area positive ions leave the surface, metal is lost and corrosion is apparent. The part of the structure with the smaller (less negative) open circuit potential at the interface is the cathode, and over this area the metal does not corrode; various reactions may occur at the cathode surface, the most common ones being either the reduction of oxygen to hydroxyl ion or the discharge of hydrogen ions. The process of electrolytic

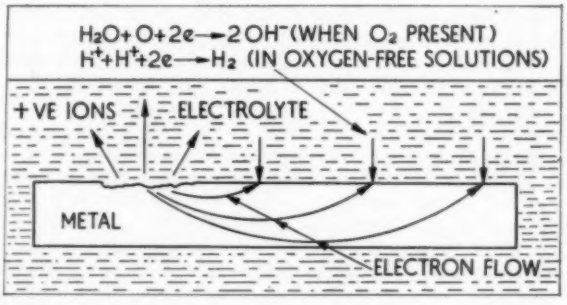


Fig. 1. The process of electrolytic corrosion.

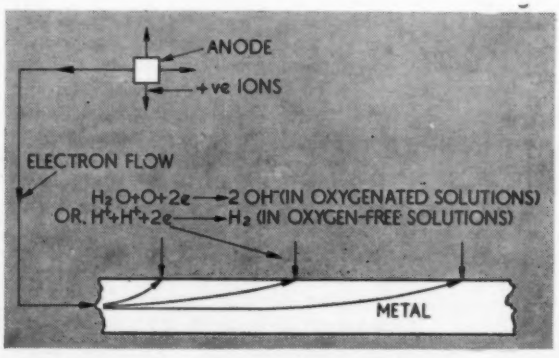


Fig. 2. The principle of cathodic protection.

*Spencer & Partners, Consulting Engineers.

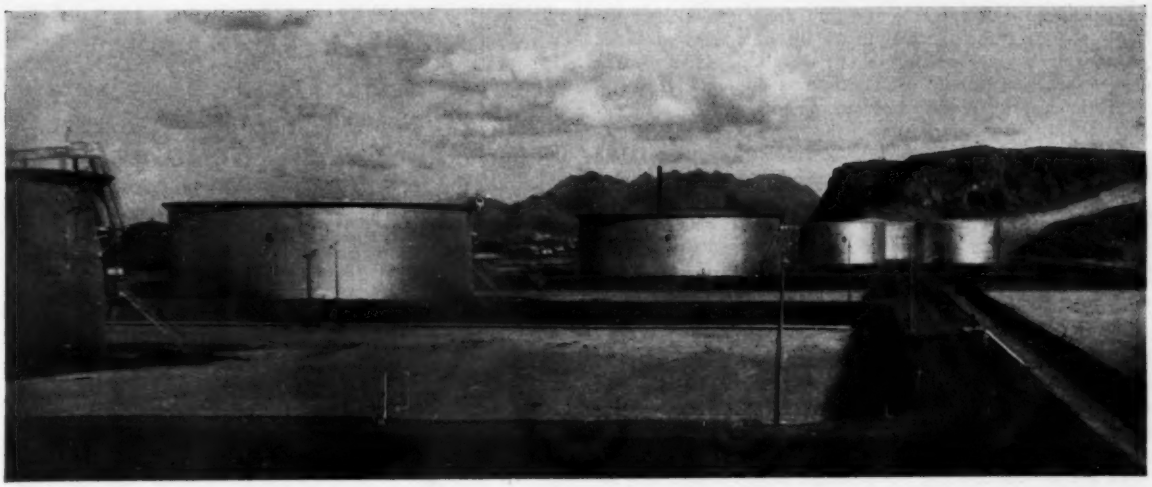


Fig. 3. Cathodically protected tank farm in Middle East.

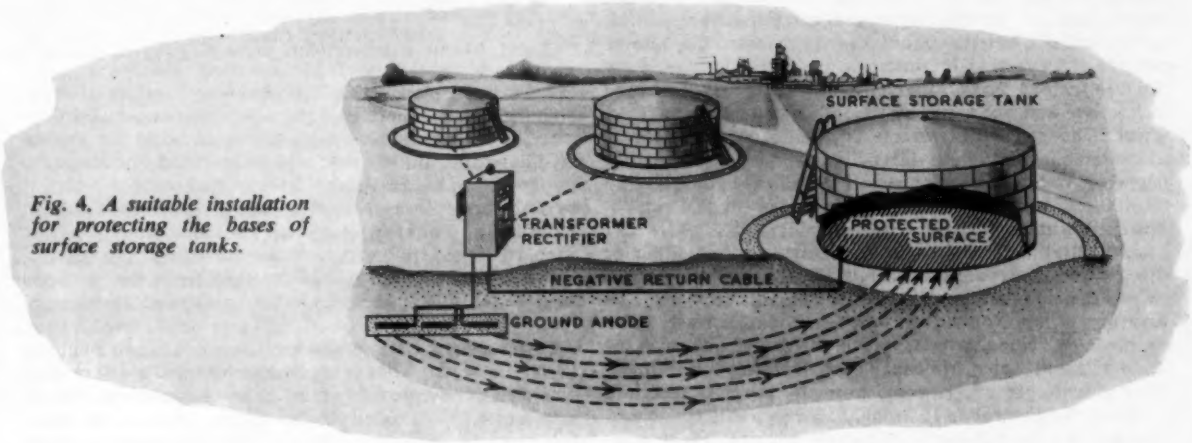


Fig. 4. A suitable installation for protecting the bases of surface storage tanks.

corrosion is shown in Fig. 1. The formation of hydroxyl ions occur readily, and in the presence of dissolved oxygen is the predominant reaction. These ions cause the electrolyte to be more alkaline at the cathode/electrolyte interface. In neutral solutions not containing oxygen, the hydrogen discharged forms an electrically resistive layer on the cathode surface and corrosion is greatly reduced.

Principle of Cathodic Protection

Since corosion is caused by the loss of positive metal ions from the surface it follows that if a current is applied from an external source so that positive ions flow to all parts of the surface, corrosion cannot occur. This is the principle of cathodic protection.

To cause positive ions to flow to the surface it is necessary to depress the metal/electrolyte potential, and this is achieved by causing electrons to flow from a source of electrons through a metallic circuit to the metal to be protected. Two reactions may occur at the metal/electrolyte interface; firstly, some of the excess electrons may be transferred across the interface and reduce oxygen to hydroxyl ion, and secondly, in absence of oxygen at the interface, hydrogen gas is evolved. The principle of cathodic protection is shown in Fig. 2.

There are two methods of applying cathodic protection; these are called respectively the "sacrificial anode" and the "power impressed" systems. The former employs a block of strongly electro-negative metal, such as magnesium, which is electrically connected to the structure to be protected and immersed in the electrolyte. The magnesium readily loses positive ions to the electrolyte, thus leaving it with a surplus of electrons: some of these flow through the metal circuit to the metal to be protected thereby depressing its potential. All corrosion then occurs at the sacrificial anode and the structure is protected. The anode is consumed and requires periodic replacement.

Power impressed cathodic protection utilises a d.c. source of power; the negative terminal of this source is connected to the structure to be protected and the positive terminal to an anode system (usually of steel or graphite), which is immersed in the electrolyte.

The a.c. source and rectifier act as a "pump" for transferring electrons from the anodes, via the metallic circuit, to the metal to be protected. The anode has a deficiency of electrons which either causes it to lose positive ions (as in the case of steel) or causes oxygen to be evolved (as in the case of graphite and platinum).

The criterion of protection is that the potential between the metal and the electrolyte at the interface must be greater than any open-circuit natural potential which existed before cathodic protection was applied. However, this value cannot readily be determined and it is usual to depress the potential of the surface to be protected to a specified value as measured in a standard manner. The value required is determined by experiment, but for mild steel in near-neutral aqueous solutions the value of −0.85 volt relative to a copper/copper sulphate half-cell has been found sufficient for protection.

Current Requirements

The value of current which flows to the surface when the potential depression is sufficient for protection varies enormously with conditions. It has already been stated that in solutions containing dissolved oxygen the principal cathodic reaction is the reduction of oxygen to hydroxyl ion; this is equally true whether the metal is corroding naturally or whether the currents are being caused to flow for the purposes of cathodic protection. The reduction to hydroxyl ions involves the transfer of electrons from the metal to the solution and hence the rate at which this reaction occurs determines the rate at which electrons must flow from the anode to the protected structure, i.e., it determines the current required for protection. The rate of arrival of oxygen at the interface is controlled principally by two factors. Firstly, the concentration of oxygen in the electrolyte and, secondly, by the thickness of the boundary layer. The range of currents required for protection is considerable being from 1-5 milliamps/sq. ft. for steel in sluggish water containing small amounts of oxygen to 50-100 milliamps/sq. ft. for steel in highly aerated rapidly moving solutions.

In neutral water, when the electrolyte contains little or no oxygen, corrosion is not usually a problem, except when the solution contains an agent for removing the hydrogen film formed at the cathodic surface. The sulphate-reducing bacteria, which thrive only in oxygen-free soils and water, are capable of removing the cathodic film of hydrogen which would normally prevent corrosion.

When the electrolyte is strongly acid it is still possible to protect ferrous surfaces, but since the hydrogen ion concentration is high, these ions are readily discharged. Considerable amounts of gas are evolved at the protected surface and the current required for protection is high—1 amp./sq. ft. or more in concentrated acids.[1]

The foregoing values of current density required for protection are for bare metallic surfaces; the current required in a practical case may be greatly reduced by treating the surface with paint or other protective coatings; current will then flow only to pinholes or other discontinuities in the protective layer. It is not normally desirable to coat surfaces across which heat transfer occurs with non-metallic coats; such surfaces are protected bare. Protective films form naturally in certain waters as discussed in the following section.

Cathodic Effects

The build-up of alkali at the cathodic surface has two effects, one beneficial and the other deleterious. Firstly, the increasing *p*H of the electrolyte makes the formation on the metal surface of a relatively insoluble film of hydroxide more probable and this helps to reduce the corrosion in the case of iron and steel. Secondly, the alkali may attack surface layers which would otherwise protect the metal. Thus, when aluminium is to be protected, care must be taken that only the minimum current required for protection flows; if the current is excessive the cathodic alkali attacks the protective surface film with the formation of aluminates and the metal may become pitted. Furthermore, if the metal to be protected is coated with a natural oil base paint, the coating may be softened and damaged by the action of the alkali.[2] When a steel surface, which is to be cathodically protected, is painted, a synthetic rubber, bituminous, or other material not attacked by alkali, should be used. If the current density is high, appreciable amounts of hydrogen will be evolved from the protected surface and this may cause the disruption and blistering of coatings.

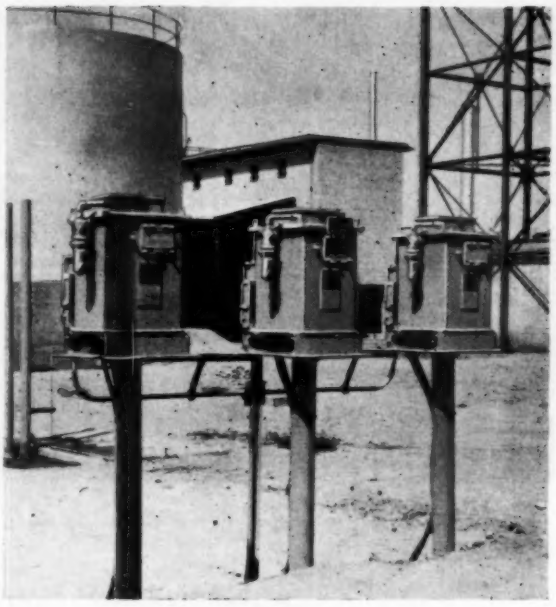


Fig. 5. Transformer-rectifiers protecting buried piping.

One further cathodic effect of note is that encountered in certain waters containing magnesium and calcium ions, where relatively insoluble films of magnesium and calcium salts are formed on the metal surface due to the lower solubility of these salts in the alkaline solution at the cathodic surface. The presence of such layers is beneficial as it reduces the current required for protection, but deleterious in that the deposits may appreciably reduce the heat transfer across the surface. The foregoing factors indicate the care required in applying the principle of cathodic protection. Despite these limitations, however, iron, steel, stainless steel, lead and aluminium surfaces have all been successfully protected.

Measurement of Potentials

To ensure that a surface is protected, the metal/electrolyte potential must be depressed to a given value. It is therefore necessary to measure this potential accurately and by a method which is suitable for practical purposes. To ensure that the results of the measurement are reproducible, a half-cell comprising a metal immersed in a solution of its own ions is employed for making electrical contact with the liquid. The two half-cells most commonly used in cathodic protection work are the copper/copper sulphate and the silver/silver chloride types. The former consists of a rod of pure copper dipping into a saturated solution of copper sulphate, and the latter, a rod or wire mesh of silver dipping into a saturated solution of silver chloride. The rod and solution are encased in a plastic tube which has a porous plug at one end as shown in Fig. 6. This plug separates the half-cell solution and the

electrolyte but gives an electrically conducting path between them. The potential between the rod of the half-cell and the metal of the protected surface must be measured with a high resistance voltmeter or potentiometer. As shown in Fig. 7, the half-cell should normally be placed close to the protected surface to reduce errors due to potential drops in the electrolyte.

Current Distribution

A greater current will flow to points on the surface near to an anode than will flow to those more remote from it. Hence, to ensure that the whole of the surface is protected, the area near the anode must receive appreciably more current than is required for its protection. This is not only wasteful of electrical power but may also cause damage to the coating near to the anode. When the anode must be placed near to the protected surface it is desirable to coat the surface opposite the anode with a material which will not be damaged by the excess current, e.g. a small sheet of neoprene.

The presence of even an indifferent coating on the protected surface will appreciably improve the uniformity of the current distribution.

Cathodic Protection Equipment

As previously discussed, the two methods of applying protection are by sacrificial anodes and by power impressed currents. The equipment for these two methods is different and it is convenient to discuss them separately.

Sacrificial Anode Method. This consists of attaching to the structure a block of a more electronegative metal such as magnesium or zinc. The type of installation is shown in Fig. 7. The theoretical value of the electrical charge which would be delivered by unit weight of the sacrificial metal may be computed from Faraday's Law, but the practical value will fall short of this figure especially in the case of magnesium as the metal block undergoes "self corrosion", i.e., it would still corrode at an appreciable rate even if it delivered no protective current.

The percentage anode efficiency is defined as:
actual/theoretical ampere hrs. per pound × 100
and typical values for magnesium and zinc are given together with values of the effective driving voltage in Table I.

TABLE I: DATA ON GALVANIC ANODES[3]

	Mg	Zn
Thoretical amp. hrs./lb.	1,000	372
Actual amp. hrs./lb.	500	335
Anode Efficiency	50%	90%
Effective driving volts*	0.85	0.25

* Against metal depressed to 0.85v

The figures in this table are typical for applications in soil and sea water and are only given here to indicate the approximate values to be anticipated. It will be seen that magnesium has a driving voltage almost three times as great as zinc, and it is therefore to be preferred to zinc in applications where the resistance of the electrolyte is not extremely low. Zinc has a high anode efficiency, and consequently when the electrolyte resistance is sufficiently low (30-100 ohm cm) it may be preferred.

"Magnesium" anodes are usually fabricated from a magnesium/aluminium/zinc alloy as this has been found to be more satisfactory than the pure metal. Zinc anodes are of the pure metal and should contain preferably less than 0.01% impurity. The approximate costs of the metals when cast as anodes are 3s. 6d. per lb. for magnesium, and 2s. per lb. for zinc.

Most of the technology developed for the use of sacrificial anodes has been associated with their applications to ferrous structures immersed in soils and sea water. When iron or steel is to be protected in other aqueous solutions, especially when the temperature is enhanced, simple tests should be carried out with the "sacrificial metal" in question to ensure that the driving voltage is positive and of sufficient magnitude. It is possible for the polarity between metals to be reversed in certain conditions; for example zinc is not protective to steel in certain solutions above 170° F., and an application is referred to later in which zinc was used sacrificially to protect aluminium.

Power Impressed Method. This consists of attaching

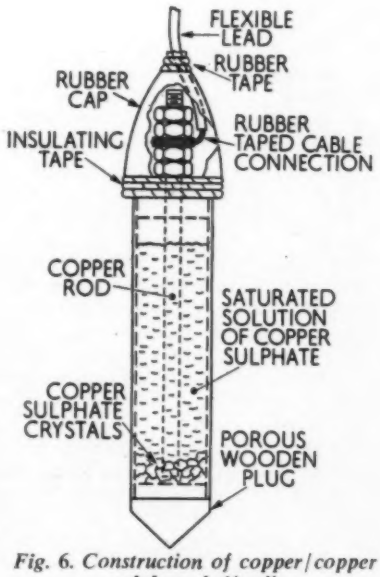


Fig. 6. Construction of copper/copper sulphate half-cell.

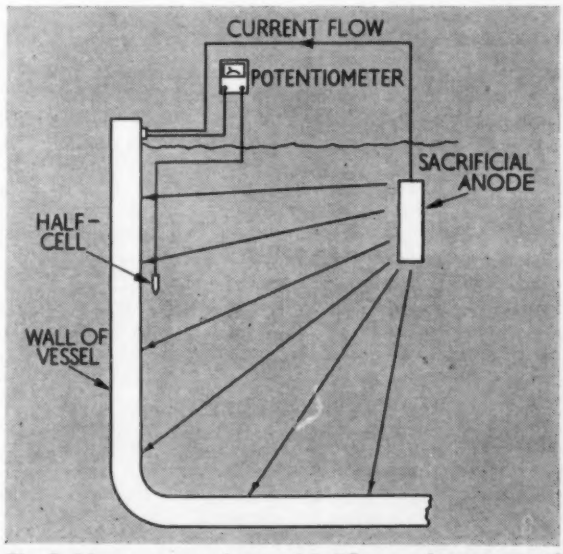


Fig. 7. Measurement of potential difference between metal and electrolyte.

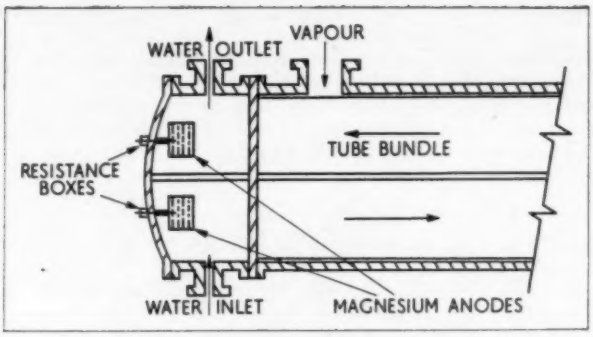


Fig. 8 (left). Platinum foil anode; the lead is encased in Araldite. Fig. 9 (above). Cathodic protection of water box of tubular condenser.

the structure to be protected to the negative terminal of a d.c. source, the positive terminal of which is connected to an anode (or anodes) immersed in the electrolyte. The d.c. source is usually obtained by rectifying power from the a.c. mains; equipment especially designed for this duty is available.

The anode materials most commonly used are steel and graphite, though silicon iron and platinum are used to some extent. Steel anodes must be replaced periodically; graphite and silicon iron do not corrode in a quantitative manner and when used at low current densities (1-2 amps per sq. ft.) have a very long life. Platinum may be used at considerably higher current densities; anodes of this metal are well suited to use in chemical plant since, for a given current output, they are much smaller in size than the other types. One disadvantage of using small anodes is that the anode/electrolyte resistance is high, thus relatively larger operating voltages are required. A platinum foil anode with an Araldite-encased stem is shown in Fig. 8.

With a power impressed system, all metal on the positive side of the d.c. source is anodic. Thus the cables to the anode must be completely isolated from the electrolyte or they will corrode with extreme rapidity. Such cables should be polythene and/or P.V.C. sheathed. This does not apply to sacrificial anodes as the lead to the anode forms part of the protected structure and is, therefore, cathodic.

Applications of Cathodic Protection

Some specific applications of cathodic protection of interest to engineers maintaining and operating chemical works are given below:

Pipelines: External Surface. There are many instances of the successful application of cathodic protection to buried ferrous pipelines, both to long lines carrying oil, natural gas or water, and to small buried pipeline systems.

Sacrificial anodes and power-impressed currents have been used; the preference is generally for the former when the soil resistance is below 2,000 ohm cm and the pipelines are reasonably well coated and of shorter length; the latter method is used when the soil resistance is high or the surfaces to be protected are poorly coated.

Since the pipeline forms part of the electrical circuit it must be a good electrical conductor. In this respect welded lines are quite satisfactory but other methods of coupling pipe sections may not be electrically continuous, and it is necessary to make measurements to determine the resistance of sections of the pipeline. If this resistance is too high, the joints must be excavated and bonded across by a short length of conductor. Alternatively, when protection is to be applied to a limited section of piping, it may be necessary to insulate certain flanges and couplings to prevent current from spreading beyond the desired limits.

When electrical currents pass through the soil, they may flow into low resistance metal structures at some points which are not included in the protective scheme and leave them at other points. Where the current leaves the metal surface, corrosion will occur. To prevent this, it may be necessary to carry out additional electrical bonding between structures in order that pipelines or cables which might otherwise be damaged are connected to the protected structure.

Sacrificial anodes are preferred for protecting pipe networks because outputs from individual anodes are small and well distributed, and the need for additional bonding is greatly reduced.

Internal Surface. The internal surface of pipelines cannot readily be protected because the cross sectional area of electrolyte available for current flow is limited, This means that the area protected by one anode is small unless the metal surface is well coated and the resistance of the electrolyte is low. Experiments have shown that protection is achieved for 2-3 diameters on each side of an anode located on the axis of a pipe. Any such installation would be costly and it would probably be cheaper to use a more resistant metal than to use cathodic protection. For further information on the design of cathodic protection schemes for pipelines and other ferrous structures readers are referred to two papers by Spencer.[4,5]

Storage Tanks. Both the external and internal surfaces of storage tanks have been successfully protected.

(i) *External Surfaces.* When surface storage tanks are in contact with a corrosive soil, their bases may be protected either by sacrificial anodes or by power impressed currents. The latter is preferable when an a.c. mains supply is readily available. A suitable installation for protecting the bases of surface storage tanks is shown in Fig. 4.

It is convenient to make metal/soil potential measurements at the periphery of the tank, and as the potential distribution across the base is not uniform, usually being less at the centre than at the circumference, it is common practice to depress the potential at the periphery to 0.90-0.95 volts (versus $Cu/CuSO_4$) to ensure protection of the whole base. The external surface of buried storage tanks may be protected in a similar manner.

(ii) *Internal Surfaces.* Cathodic protection has been used for preventing the corrosion of the internal surface of water tanks. When the area to be protected is small, one anode placed axially in the tank may be sufficient; when several anodes are required they should be positioned so as to make the current distribution to the protected surface as uniform as possible. With rect-

angular tanks, particular care should be taken in design and subsequent measurement to ensure that the corners and other recesses of the tank are at protective potentials.

Heat Exchangers. Corrosion is frequently encountered on the ferrous end covers and dividing partitions of tubular heat exchangers having non-ferrous tubes and tube plates. When the coolant is of low electrical resistance, such as sea water, sacrificial anodes installed as shown in Fig. 9, are effective in preventing corrosion. Both zinc and magnesium have been used for this purpose. If the installed anodes deliver more current than is required for protection, a resistor may be installed in series with the anode lead.

When the electrolyte resistance is high it is necessary to use power impressed currents. For this purpose platinum anodes are particularly suitable since their small size means that for a given current rating they cause a minimum of obstruction and may be easily installed and removed for inspection without removing the end cover. Protection is not normally achieved for more than 2-3 diameters along the tube from the face of the tube plate. In all cases it is desirable to coat the internal surfaces of the water box in order to reduce current requirements and improve potential distribution.

Usually the tubes of a tubular heat exchanger are too close together to allow cathodic protection to be applied to their outside surface, but a case is recorded in which zinc strips were used successfully to protect the outside surface of aluminium tubes which were in contact with cooling water.

Coil Type Heat Exchangers. Coils immersed in a corrosive coolant have been successfully protected by both magnesium anodes and power impressed currents. Mild and stainless steel have been treated in this manner. When the liquid outside the tubes contains appreciable magnesium and calcium ion concentrations care must be taken that the potential on the coil is not sufficient to cause the deposition of a calcareous deposit which will interfere with heat exchange. For steel the potential should be maintained close to 0.85 volt (relative to $Cu/CuSO_4$ half cell).

Aluminium cooling coils in softened water have been cathodically protected by the use of zinc strips.[6]

Pumps. Because of their small dimensions pumps do not lend themselves to cathodic protection, but sacrificial anodes have been used to protect parts of pumps such as the shaft and strainer box as discussed by Raclot.[7]

Wet Gas Holders. The application of cathodic protection to the immersed surface of wet gas holders is described by Weiler and Heymans.[8]

General. The moving underwater equipment of clarifiers, flocculators[9] and oily-water separators have been protected. The structural members of rotary screens can be protected but the current requirements are high.

Fig. 6, courtesy of Metal and Pipelines Endurance Ltd.

REFERENCES

1. Uhlig, H. "Corrosion Handbook," p. 929.
2. Sudrabin *et al.* "Some effects of cathodic protection on conventional paints," *Corrosion*, March 1952, 109-114.
3. Wahlquist and Fanett. "Practical use of galvanic anodes"; paper given in N.A.C.E. Symposium on Cathodic Protection, Pittsburgh 1947.
4. Spencer. "Cathodic Protection in Relation to Engineering Design", *Chemistry and Industry*, 1954, **1**, 2-10.
5. Spencer. "The Water Engineer and Cathodic Protection", *Journal of the Institution of Water Engineers*, 1956, **10**.
6. Mears and Fahrney. *Trans American Inst. Chem. Eng.*, 1941, **37**, 911.
7. Raclot. "Cathodic Protection and Magnesium Anodes—Application to Pumps", *Metaux*, 1953, Nos. 335-336, **28**, 319-322 (French).
8. Weiler and Heymans. "Cathodic Protection of Wet Gas Holders", *Revue Generale du Gaz*, 1952, Nos. 5-6 (Belgian).
9. Merrithew. "Cathodic Protection of Moving Underwater Equipment", *Corrosion*, March 1952.

The Technological Awakening

IN his presidential address to the Institution of Chemical Engineers on 24th April, Mr. John A. Oriel appealed to all the members to make technological education their main concern over the next few years. "Assist the universities and technical colleges; assist those who are preparing courses; give lectures yourselves, and assist boys in every way possible to see the privilege that lies before them in taking part in industrial development," he said.

He referred to the great awakening in Britain to the value and need for technical developments, and in particular for improved technical education. He welcomed what he called the new approach to technology, and throughout his speech it was evident that he had the Government's White Paper particularly in mind. He continued, "It would only be right for us to see what we can do to assist the progress of technology rather than to criticise the authorities for tardiness. The Government now appears ready to do all it can to make up for what we know to have been a gross error of judgment over many years. Sir Anthony Eden in September last at Leamington Spa said that the historian of the future would see the 1950's as a period when material possibilities hitherto undreamed of were beginning to unfold. There was one condition to this—that the world preserved its sanity. We in science and technology have reason to be proud of the part we have played in improving the material benefits of the world, but we cannot shrug our shoulders and believe that the second part of the Prime Minister's statement has nothing to do with us."

Naturally technologists are different from those who received their education in the arts, for different disciplines produce different qualities. The balance must now swing away from the classics to science. Mr. Oriel remarked that it is archaic that our largest industries—our nationalised industries—that are highly technical in character, are controlled by men without technical knowledge and by retired soldiers. With such great technical improvements at hand, he regretted that in Britain we do not have at the head of affairs men with technical imagination, capable of inspiring those who are attempting to work under them.

Referring to the contribution the universities can make to the expansion of technical education, Mr. Oriel said they should endeavour to provide teaching staff for the technical colleges in ever-increasing numbers. They could, too, quite reasonably help to improve the status and outlook of the teaching staff of the technical colleges by asking them to assist in research and by allowing more of the research work carried out at the technical colleges to rank for the preparation of theses for the Ph.D. He criticised the tendency of the universities to hang on to their graduates far too long. For those entering industry or teaching, three or four years is long enough; a longer period is enervating. The men who clearly would make first grade technologists, should move on to a new college to receive post-graduate technological education. This "All Souls of Technology" should also receive men who have spent 2-5 years in industry. There, men straight from the university and others from a variety of industries could rub shoulders with one another. There, we could expect to find such an exchange of ideas and techniques as would really make this country a leader in quality of technologists, knowing full well that we cannot hope to lead in quantity. He said that it is in the realm of the technical colleges that the greatest advance in planning had been made recently. "We in our various walks of life, whether as teachers, research workers, or managers in industry, must do all we can to see that this new scheme is a success," he concluded.

The Force-Balance System of Fluid-Flow Control

How the force-balance principle solves difficult industrial problems of fluid-flow measurement and control

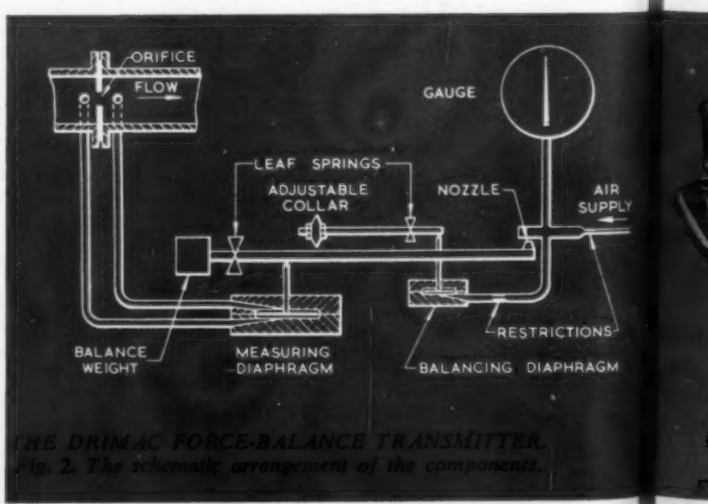
by
K. GOITEIN*

(*Photo: British Petroleum Co. Ltd.*)

A group of Drimac transmitters measuring flow at the Aden refinery.

IN common with many other industries, the chemical industry uses fluids extensively as carriers of chemical energy (e.g. fuel oil, heating gas) or thermal energy (e.g. steam, hot water or brine). Flow control problems specific to the chemical industry, however, arise mainly in conjunction with the use of fluid chemicals as ingredients or reagents which have to be supplied in measured quantities into reactors or other processing devices. Such fluids are often highly reactive, poisonous or inflammable, and instruments and regulators dealing with these fluids must therefore be designed to eliminate or minimise hazards. In this respect, force-balance pneumatic flow transmitters have been found particularly useful and adaptable.

The fundamental variables of a chemical process, i.e. flow rate, pressure, temperature and level, differ greatly in their general characteristics and, therefore, require different methods of regulation and control. Flow rates are perhaps the most easily controllable variables, because time lags between correcting actions (valve spindle movements) and corresponding flow rate changes are generally



THE DRIMAC FORCE-BALANCE TRANSMITTER.
Fig. 2. The schematic arrangement of the components.

*Elliott Bros. (London) Ltd.

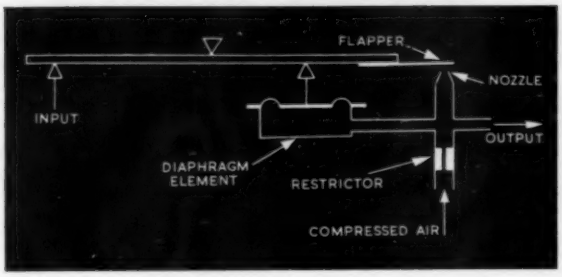


Fig. 1. The principle of the force-balance transmitter.

small. In this respect, fluid flow resembles electric energy flow with its instantaneous response to correcting action. It is perhaps due to this property of fast response that fluid flow control is generally the most important part of any control system.

In the chemical industry, flow control often presents specific problems. Fluids used in chemical processes are often highly reactive, and equipment must be designed so that all parts in contact with the fluid are corrosion resistant. Such parts must be capable of being produced in a number of different materials to suit the particular fluid processed. An equally important consideration in many cases (e.g. in food processing plant) is that contamination of the processed fluid through contact with any parts of instruments must be excluded. In these instances, provision must be made for purging (either periodic or continuous) or disinfecting. This requirement excludes the use of the mercury manometer type of flow meter. The nature of the fluid sometimes requires special precautions against fire or explosion hazards. In this case, electrical methods of measurement and transmission are at a disadvantage compared with pneumatic methods because of the expense of flameproofing or because air-purging arrangements become necessary. Absolute leakproofness is of paramount importance in view of the dangers arising from the escape of many of the chemical process fluids.

The standards of accuracy, sensitivity and dependability are often more exacting than in other industries; maintenance work needs to be minimised and should be capable of being carried out without process interruption.

In order to derive the full benefit from the fast response of flow rate to valve movement it is essential that the measurement lag should be reduced to the minimum.

Flow Rate Measurement

Of the various types of flow meters used in process control, it is undoubtedly the constant area differential pressure flow meter which is capable of the most general application in the chemical field. Instruments with rather limited uses in this field include the positive displacement meters, the variable area meters (e.g. rotameters, weir meters) or the more recently developed instruments utilising electromagnetic or thermal effects; a variety of reasons restrict their usefulness in chemical process control, e.g. corrosion and fire hazards; where large flow rates are concerned the cost of such instruments is high.

The constant area differential pressure flow meter is a comparatively simple and cheap device. It consists of a constant restrictor (such as an orifice plate, a flow nozzle or a Venturi tube) inserted into the flow line and an instrument measuring the pressure drop or differential pressure across it. The relationship between this pressure drop and the actual flow rate has been thoroughly investigated so that, under most practical conditions, it is possible to estimate flow rates, with a reasonable degree of accuracy, from the pressure drop. Orifice plates are simple and cheap devices even for very large pipes and can easily be manufactured from a variety of corrosion-resistant materials. Their principal drawback is a high pressure loss, amounting to about 50% or more of the useful differential pressure. Since the latter cannot be arbitrarily reduced without impairing the accuracy of the flow measurement, the pressure loss of an orifice plate may sometimes become prohibitive and a more expensive Venturi tube has to be used; this has a pressure loss of only about 10-20% of the useful differential pressure. It has certain other advantages; there is less turbulence and therefore reduced corrosion and erosion effects, while better accuracy is maintained over long periods. This often justifies the considerably higher cost.

The conventional mercury manometer flowmeter is not ideally suited for the control of chemical processes in general. Mercury is incompatible with many of the fluids used in the chemical industry; furthermore it is poisonous and therefore objectionable in food processing. The response of a mercury manometer is comparatively slow,

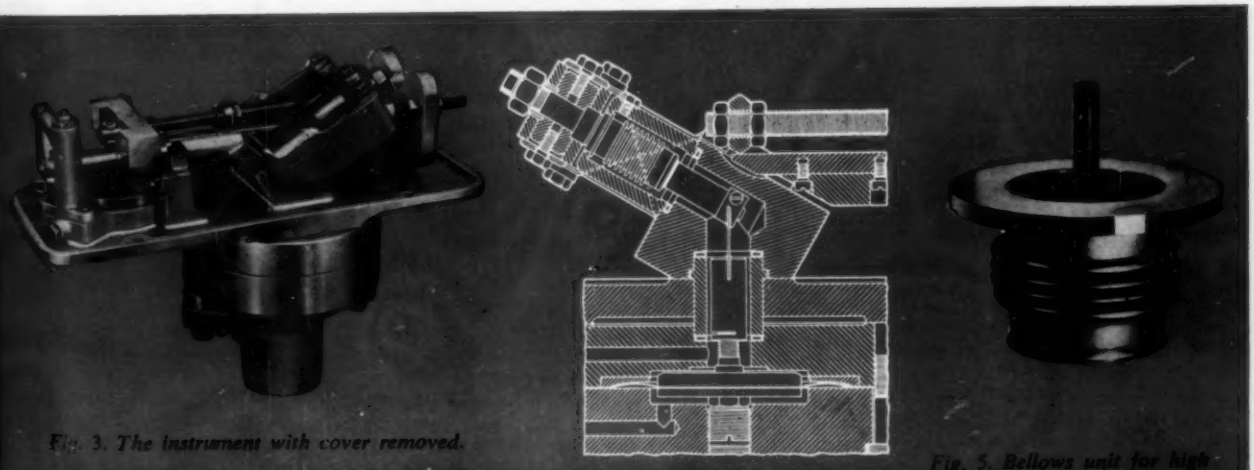


Fig. 3. The instrument with cover removed.

Fig. 5. Bellows unit for high differential pressure

because of the inertia of the mercury and of the fluid contained in the impulse lines; response time constants of the order of ½-1 min are not uncommon, as against flow response to valve action constants of the order of 1-2 sec.

Force-Balance Flow Measurement

The progress of automation in the chemical industry has led to the development of a flow meter and pneumatic transmitter which is chemically inert and fast responding; this is the so-called D.P. cell or force-balance flow transmitter. Various instruments working on the same basic principle are now on the market. This type of instrument has now generally been accepted as an essential element of fluid flow control systems. Force-balance methods of measurement are by no means new; their prototype is a pair of scales. An unknown force is measured by opposing it with a known force, which is adjusted to achieve balance. Some people regard the term "force-balance" as somewhat misleading. It could be argued that a spring balance, which is a typical deflectional instrument as opposed to a force balance instrument, also balances an unknown force against the calibrated spring force. The essential difference is a matter of position or movement. Whereas in the deflectional instrument the position at which balance is achieved is a measure of the force, the force-balance instrument is a null instrument. In the latter, an external power supply is required; this may be provided by a manual operator; alternatively, in the case of an automatic system, power can be supplied by compressed air. A simple electrical analogy will illustrate the difference between the two kinds of instruments; electrical forces can be measured by the deflection of a control spring (deflectional meter), or it can be measured by the potentiometric method in which an e.m.f. is opposed with another e.m.f. of equal magnitude and known value; the balance is achieved by adjustment of the latter.

The advantages of the force-balance method derive basically from the fact that the energy required to operate the measuring instrument is not supplied by the process but by an outside power supply. The force-balance instrument is, therefore, an amplifier, supplying ample output power for very small input signals. Furthermore, since the input signal supplies a force only but no power, there is no appreciable displacement on the input side of the force-balance instrument; consequently there is no flow of fluid through the impulse lines (apart from compression effects), and therefore no resistance capacity or transfer lags. This is, of course, strictly true only in an ideal force-balance system; in practice some minute displacements of the balance are unavoidable, but these are quite negligible in well designed instruments of this type. Where no displacement occurs corrosion and contamination problems are simplified because the stiffness of any diaphragm seals inserted in the impulse lines does not affect the pressure transmission.

Apart from these functional advantages, the force-balance instrument is superior to the deflectional instrument from the mechanical design angle.

Since the movement is small the use of comparatively stiff elastic suspensions (e.g. cross spring pivots) makes the instrument practically frictionless, similarly frictionless elastic pressure seals (i.e. bellows or torque tubes), which are suitable for high pressures and of considerable stiffness, can be used.

The measuring element, generally either a diaphragm or a bellows assembly, contains no moving parts in the ordinary sense and therefore lends itself to corrosion-resistant design. Diaphragms can be made from a number of materials to suit almost any medium; bellows and

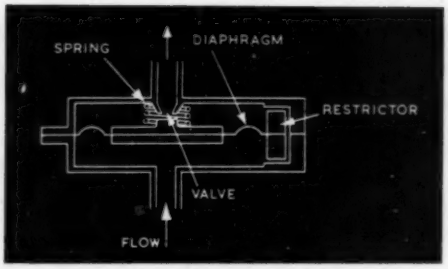


Fig. 6. Schematic diagram of self-contained flow-rate regulator.

housings are commonly made from stainless steel, or they can be suitably plated or surface-treated. Liquid seals or purges can be arranged without difficulty.

The Force-Balance Transmitter

The action of the force-balance transmitter is based on the well known flapper/nozzle effect. Fig. 1 shows the basic principle schematically. A very small movement of the *flapper* in front of the *nozzle* which is supplied with compressed air through a *restrictor* cause a large variation of pressure. Movement from the fully closed position, in which the reaction pressure equals the supply pressure (i.e., maximum value), to the fully open position in which the reaction pressure drops to almost zero is of the order of 0.001 in. for a suitably designed arrangement. It follows that any small unbalance of the beam produces a comparatively large output signal, which is fed back into the reaction *diaphragm element* correcting the unbalance. The result is a continuously and automatically balanced system, in which the output pressure is practically proportional to the input force.

The response time constant of such a transmitter is of the order of milliseconds, which makes it eminently suitable for control purposes. Transient oscillatory response can be eliminated by damping devices, such as oil dashpots and resistant-capacity elements introduced into the feedback loop. These devices will also reduce the effects of random flow variations.

Fig. 2 shows a schematic diagram, and Fig. 3 a picture of a typical force-balance type flow transmitter with the cover removed to show details of its mechanism. These illustrations show that the balancing beam is compounded of two beams with an interaction collar which is adjustable for the purpose of varying the range. Zero adjustment is carried out by means of a balance weight or a spring, so that the output pressure for zero input can be adjusted to any desired value within the range of the instrument (usually 3-15 psi). An oil dashpot and a restrictor are provided for damping purposes.

An important feature of transmitters of this type is their high static pressure rating, due to the particular arrangement of the pressure seal (Fig. 4). This consists of a welded stainless steel bellows so positioned that the resultant static pressure force has no moment about the cross spring pivot. Even a high static pressure does not, therefore, affect the balance of forces. A fine adjustment device is provided for correct relative positioning of sealing bellows and cross spring pivot under normal static pressure conditions. Due to this seal arrangement it is possible to measure accurately differential pressures as low as 15 in. W.G. at static pressures up to 1500 psi. Fig. 4 also shows the arrangement of a diaphragm measuring unit with closely adjustable overload stops, which allow the application of at least ten times the full-scale differential pressure without there being any risk of damage to

the structure of the instrument. A bellows unit for measuring higher differential pressures is shown in Fig. 5.

The same principle is used in a number of different instruments, the details of design being altered to meet different process problems. For instance, alternatives to cross spring pivoting are ball or knife edge bearings; these are not, however, frictionless to the same degree at the highest bearing pressures. Since the latter depend on static pressures, not on differential pressures, friction can be prohibitive when very high static pressures are involved even though the friction coefficient is very low. Again, there can be differences in the design of pressure seals. In the instrument which has been described above there is a "zero moment" seal; in some instances, this type of seal is replaced by two balanced seals, one on each side of the measuring diaphragm or bellows. In applications where very high static pressures obtain, the "balanced seal" design is inferior to the "zero moment seal."

Controllers and Accessories

The considerations showing the superiority of the force-balance transmitter compared with the deflectional instrument apply equally to controllers and their accessories. The force-balance device does not load the signal and therefore does not affect its action. It is, in principle, a feedback amplifier, the output power of which is supplied from an independent source. There are two basically different types of force-balance controllers on the market; these are respectively the *stacked diaphragm type* and the *balanced beam type*. The working principle involved is very similar to that of a transmitter; in fact a pneumatic transmitter can, in certain circumstances, be used as a simple controller.

The force-balance controller is, like the transmitter, a self-balancing mechanism in which an input force is automatically and continuously balanced by means of a flapper-nozzle type amplifier and feedback arrangement. In the case of the controller, however, the input force is the difference between the measured value and the desired value (i.e. the error signal). A computer element is introduced into the feedback loop, which modifies the relationship between the balancing or feedback force and the output pressure. The computer element produces proportional, derivative and integral control functions, which are individually adjustable to give optimal control. Here again, the virtue of the force-balance system is apparent: the input (i.e., the error signal) is not loaded, and it is not required to do any work towards supplying the controller output power. Transmission lag, therefore, is small even for long distances, and high sensitivity is achieved.

Further elements of the control loop which are normally designed as force-balance devices are pressure regulators and pilot or booster valves. The former is used to supply air at a regulated pressure (usually 18-20 psi) to any of the force-balance devices in the control loop; alternatively the air pressure can be adjusted to the desired input value of the controller. It is also used for manual loading of an air-operated control valve. The purpose of the pilot valve is to reduce transmission lags between transmitter and controller, and between controller and valve. Both devices are similar in their action and in their design. Their esential components are of a diaphragm or bellows, an inlet valve and an exhaust valve. The input pressure is an adjustable spring pressure in the case of the pressure regulator, and a pneumatic pressure in the case of the pilot valve. The inlet and exhaust valves are operated by the difference between these two pressures, so that balance is automatically maintained.

One of the aspects of modern control systems in which force-balance devices play an increasingly important part is standardisation of the elements of the control loop. Operating pressures of pneumatic control systems are now generally standardised at 3-15 psi. The output pressure range normally conforms to this standard, independent of the nature or range of the process variable. The controllers are, therefore, interchangeable. The indicators and recorders are simple pressure gauges of standard range. The latter are available in the form of miniature instruments recording or indicating up to three variables (e.g. measured value, desired value and valve input pressure). They frequently include a pressure regulator (which is manually set to give the desired value); a change-over valve is usually provided to allow one to switch from automatic to manual operation of the controller if required. These miniature instruments are proving increasingly useful in complex control systems. A large number of these instruments can be arranged conveniently on a small "graphic" panel.

Special Applications of Controllers

Control of very small flow rates. Where the flow rate to be controlled is small (e.g. in analysis of a gas sample, in purge or leak detection applications), it is often possible to dispense with a flow transmitter and to use a self-contained flow rate regulator directly inserted into the flow line. Fig. 6 shows the principle of such a device.

Flow Ratio Control. This is a frequent requirement in chemical plant control systems. It is used, for instance, to achieve economic combustion conditions by controlling the ratio of fuel to air flow; another example is for the adjustment of some quality (e.g. calorific value) of a mixture of fluids. In this form of control, two flow transmitters supply signals into a ratio controller. This is an ordinary controller combined with a multiplying device (proportionator), which modifies one of the signals by multiplying it by the ratio factor. The proportionator is a force-balance device with an adjustable leverage; adjustment is effected either manually or automatically. In the second case, the output of a controller may be used to adjust the ratio of two flow rates; this is a form of cascade control.

Cascade Control. Cascade control generally is a form of control in which the desired value of one controller is automatically adjusted by the output of another. Thus, flow controllers may be cascaded with level controllers or temperature controllers and the result is an improvement in the over-all control.

Quality Control. This is a comparatively recent concept based on the following considerations. To achieve a desired quality in the end product of a process, it is necessary to control automatically as many of the variables as possible. The desired values of the individual variables of the process are normally adjusted by hand according to a preconceived plan.

However, even with most careful calculations, it is not always possible to predict exactly the influence of any single variable on the quality of the end product, or to control closely all the variables affecting it. Desired value settings have, therefore, to be modified to correct any deviations in the chemical composition or the physical properties of the end product. This can eliminate the need for chemical or physical test, and so save valuable time. The force-balance principle is thus seen to be one of the foundations on which automatic control can be based.

READING LIST

The Instrument Manual, United Trade Press, 1949.
D. P. Eckman, *Industrial Instrumentation*, London, Chapman & Hall, 1950.
R. F. Stearns *et al. Flow Measurement with Orifice Meters*. New York, Van Nostrand, 1951.
A. Linford, *Flow Measurement and Meters*, London, Spon, 1949.
T. J. Rhodes, *Industrial Instruments for Measurement and Control*, New York, McGraw Hill, 1941.

The Principles of Gas Separation — I

The demand for chemicals derived from gas-separation plants is rapidly expanding. Despite this the fundamentals underlying the design of such plants are seldom described. This series takes a new look at the subject

by N. W. ROBERTS, M.A., F.R.I.C.*

THE separation of gases is a subject of great and increasing industrial importance. Before World War II the art of design of gas-separation plants was best known in Germany and in France. Since that date designers in the United Kingdom and in the United States have been stimulated by the phenomenal growth in the demand for both high and medium purity oxygen, for olefines, and for other by-products of refinery waste gases, and they have placed the art on a more scientific basis by applying general chemical engineering design methods to the problems involved. Several teams in Europe are attempting to carry operating temperatures to a new low level by tackling the problem of the separation of heavy hydrogen from ammonia synthesis gas by the distillation of liquid hydrogen and with the successful operation of this process on the industrial scale, the last temperature barrier will have been forced.

The first consideration in the design of a flow sheet for a low-temperature gas-separation process is the development of refrigeration. Refrigeration has to be provided to make up for the heat influx from the surroundings, for the losses due to the temperature differences at the warm ends of the heat exchangers, for the theoretical and practical work of separation, and for the sensible heat which may be involved in the withdrawal of liquid products (e.g. liquid oxygen). In order to pump up these quantities of heat to the temperature of the surroundings, it is necessary to do work. The only practicable way to do this work is by compressing a gas, and this is usually the gas which is to be separated, though another gas could be used for this purpose.

*Costain-John Brown Ltd.

LIST OF SYMBOLS

C_l = specific heat of liquefied compressed gas
C_p = specific heat of compressed gas
I = total heat of liquefaction of gas
L_c = latent heat of liquefaction of compressed gas
T_c = temperature of compressed gas
T_l = temperature of liquefaction of compressed gas
T_s = temperature of surroundings
T_r = temperature of returning separated products
$\Delta T = T_c - T_s$
K = constant defined in text
x = fraction of feed gas unliquefied
ε = fraction of feed gas passing through liquefier
η = efficiency of expansion machine
γ = ratio of specific heats of gas

Economic Operation Essential

Since refrigeration is an expensive utility, especially where very low temperatures are involved, it is essential for economic operation to recover as much as possible of the sensible heat (or cold) content from the products of the separation by heat exchange. A system of heat exchangers is, therefore, the first essential component of a low-temperature gas-separation plant, and the design and arrangement of these heat exchangers has a profound effect on the efficiency of the plant.

There are two ways in which the compressed gas may be expanded with the production of low temperatures, and ideally we may call these isentropic and isenthalpic expansion. The former is also often called adiabatic expansion, but since both types are carried out adiabatically (i.e. without influx of heat) the distinction is necessary. Isentropic expansion is carried out in an engine or turbine, whereas the isenthalpic expansion is effected by throttling in a valve. In practice, of course, ideal isentropic expansion can never be achieved, and some inefficiency is bound to result.

In considering the design of a gas-separation plant, we therefore first consider the refrigeration circuit without reference to the separation process which follows it. Let us consider a system consisting of two heat exchangers and an expansion engine or turbine as shown in Fig. 1. The compressed gas passes through the first heat exchanger in countercurrent with the gaseous product of the separation process, and then splits into two streams. A fraction (ε) of the cooled compressed gas passes through the second heat exchanger, again in countercurrent with the gaseous products of the separation process, while the remainder ($1-\varepsilon$) is expanded in the engine with an efficiency η. The gas which has been cooled in the heat exchanger is expanded in a throttle valve as shown

to the pressure of the expansion engine exhaust. The two streams are then mixed and subjected to whatever separation process is intended, and a liquid product $(1-y)$ is withdrawn. The still gaseous remainder (y) is warmed to atmospheric temperature by passing through the two heat exchangers in series.

The Different Cycles

This generalised circuit incorporates all the elements usually found in gas-separation plants, though in some of the more complex processes some thought may be required to disentangle the simple elements. The complications arise for reasons which will be dealt with later. With reference to the "standard" liquefaction circuits, those familiar with the subject will see that the generalised circuit (Fig. 1) corresponds to the Claude cycle. If, however, ε is made equal to 1 (i.e. all the feed gas goes through the liquefier), we have the Linde cycle; when the first heat exchanger is omitted we have the Heylandt cycle. When $y = 1$ there is, of course, no liquefaction.

If we now consider the behaviour of an ideal gas in such a circuit, we may, for convenience, assume that the heat exchangers are ideal, having infinite surface. (The effect of this assumption on the results will be discussed later.) In an ideal gas, of course, the specific heat C is independent of pressure, so that in the first heat exchanger the heat capacities of the two streams will be in the ratios of their flows, i.e. as $1 : y$. The compressed gas, being in greater flow than the products, will cool down rather more slowly than the products warm up; if at any point in the exchanger the temperature of

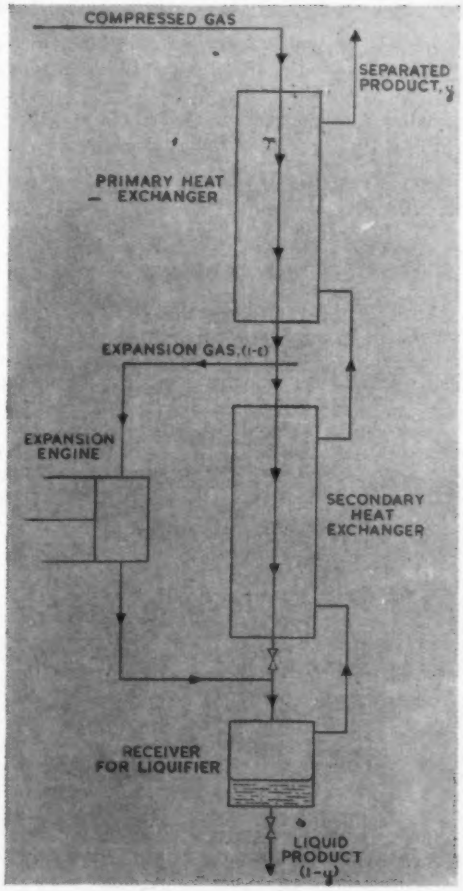
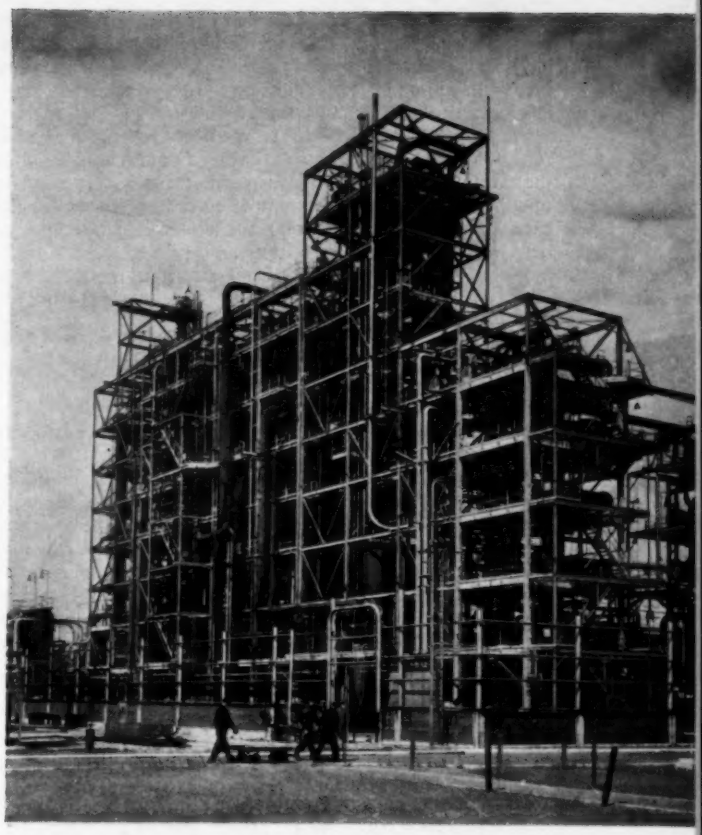


Fig. 1. Generalised refrigeration system.



An example of the outcome of the designers' efforts. The I.C.I. olefine gas separation plant at Wilton.

the compressed gas is T_c and that of the products T_p, then

$$T_o - T_c = y\,(T_o - T_p)$$

$$y\,T_p = T_c - T_o\,(1-y) \quad \text{.....(1)}$$

where T_o is the temperature of the surroundings (we have assumed an ideal heat exchanger, and, therefore, the temperatures of the two streams are equal), and ΔT is the difference in the temperatures of the two streams.

If, as in Fig. 2, we plot the temperature difference ΔT against $T_o - T_p$, we find a straight line passing through the origin as shown. On passing into the second exchanger, however, the slope changes abruptly because the quantity of compressed gas has been reduced to ε, as the expansion engine stream is removed at this point. We may distinguish three conditions for the second exchanger, which arise as the value of ε alters; these are shown in Figs. 3, 4, and 5.

When ε is small, the compressed gas will be wholly liquefied and sub-cooled to the temperature of the products emerging from the separation process. This condition is shown in Fig. 3, where we may distinguish the zones where the compressed gas is (*a*) cooled to the condensation point, (*b*) liquefied, during which process the product stream is warmed considerably without any change in T_c, and (*c*) subcooled, where the compressed liquid is cooled until ΔT becomes zero.

The Condition for Maximum Efficiency

When ε is large, then the heat capacity of the product gases may be insufficient to liquefy the whole of the compressed gas; it will in any case be insufficient to sub-cool it completely. Such a case is shown in Fig. 4, and it will be seen that ΔT

becomes zero at the point at which liquefaction takes place. At some value of ε intermediate between those discussed we have the condition corresponding to Fig. 5, where ΔT becomes zero at three points. It will now be shown that the maximum efficiency is obtained under this condition.

We have already assumed that the heat exchange losses are zero. Hence the net cold production of the cycle is equal to the work performed by the expansion engine. It may be obtained by computing the temperature drop effected in the expansion engine and retaining the assumption of a specific heat which is independent of pressure.

We may use the well-known expression for isentropic expansion

$$\frac{T_1}{T_2} = \left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}} = K \quad \text{.....(2)}$$

where γ is the ratio of the specific heats of the gas,

K is a constant as defined above,

to find the expansion engine cold production at any given inlet temperature.

It will be clear from the previous discussion of conditions in the two heat exchangers that by manipulation of the main variable ε any chosen operating conditions can be attained. The temperature of the gas entering the expansion engine is given in every case by the intersection of the two lines corresponding to the conditions in the two exchangers. It will be realised that $1-y$ (the proportion of the gas which is liquefied) will be a dependent variable, whose value is fixed when the other conditions are fixed. *The whole system is therefore governed by the single variable ε.*

When ε is large we have for the conditions in the liquefier,

$$\varepsilon\,(T_c - T_l) = y\,(T_p - T_l)$$

$$yT_p = \varepsilon T_c + (y-\varepsilon)T_l \quad \text{.....(3)}$$

where T_l is the temperature of liquefaction of the compressed gas. Combining equations (3) and (1), we get

$$T_c\,(1-\varepsilon) = T_o\,(1-y) + T_l\,(y-\varepsilon) \quad \text{.....(4)}$$

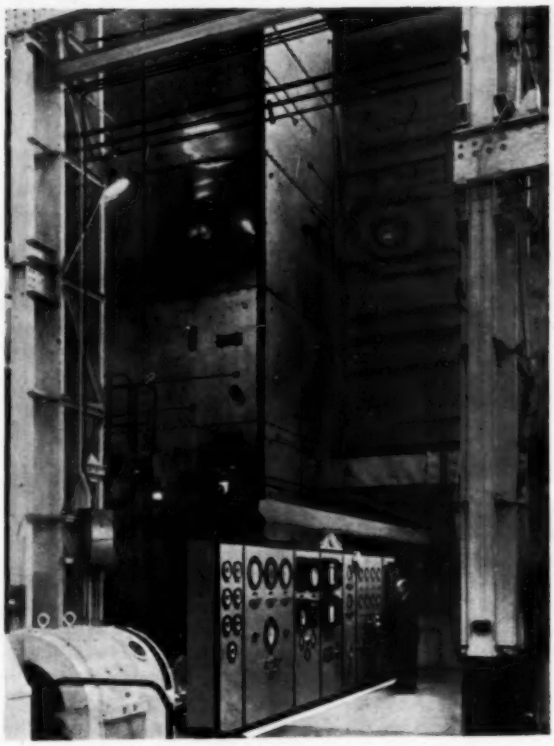
Since this value of T_c is obtained by combining equations (1) and (3), it must correspond to the expansion engine inlet temperature, and we may use it to calculate the net cold production of the system

$$\eta C_p T_c\,(1-\varepsilon)\,(K-1)/K \quad \text{.....(5)}$$

This may be equated with the amount of liquid produced, so that

$$L\,(1-y) = \eta C_p\,T_c\,(1-\varepsilon)\,(K-1)/K \quad \text{.....(6)}$$

where L is the total heat of condensation of the liquid.



Rectification tower and control panel of a 50-ton/day liquid oxygen plant. Photo: British Oxygen Co.

Eliminating T_c from equations (4) and (6), we get

$$\frac{KL}{\eta C_p\,(K-1)} = T_o + T_l\,\frac{y-\varepsilon}{1-y} \quad \text{.....(7)}$$

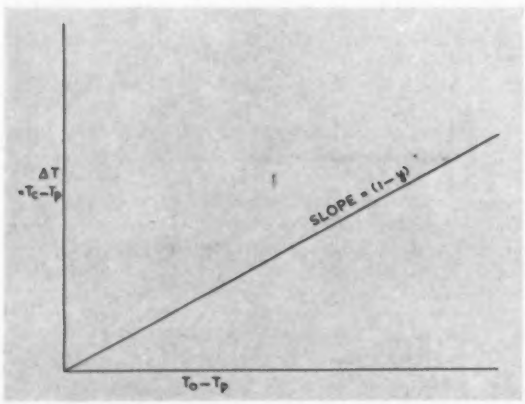
and on differentiating,

$$0 = \frac{T_l}{(1-y)^2}\left\{\frac{dy}{d\varepsilon}\,(1-\varepsilon) - (1-y)\right\}$$

Hence

$$\frac{dy}{d\varepsilon} = \frac{d\,(1-y)}{d\,(1-\varepsilon)} = \frac{1-y}{1-\varepsilon} \quad \text{.....(8)}$$

In other words, if the amount of gas passing through the



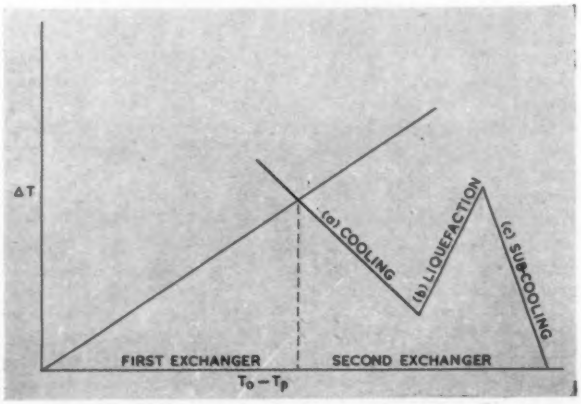


Fig. 2. (left) Primary Heat Exchanger. Relation of temperature differences in exchanger and surroundings for a given fraction liquefied. Fig. 3 (right) Quantity of compressed gas through expansion engine—too large.

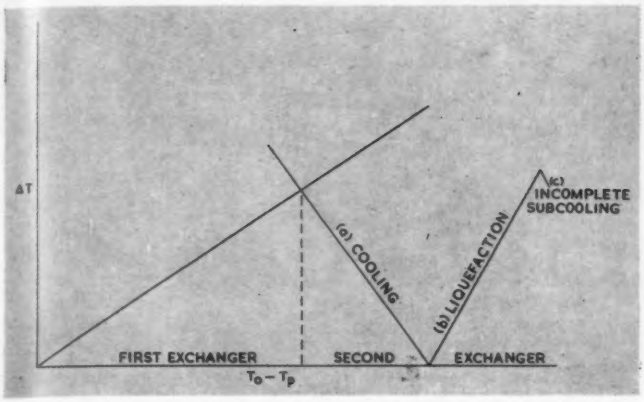


Fig. 4. Graph showing the result of having too small a quantity of compressed gas to expansion engine.

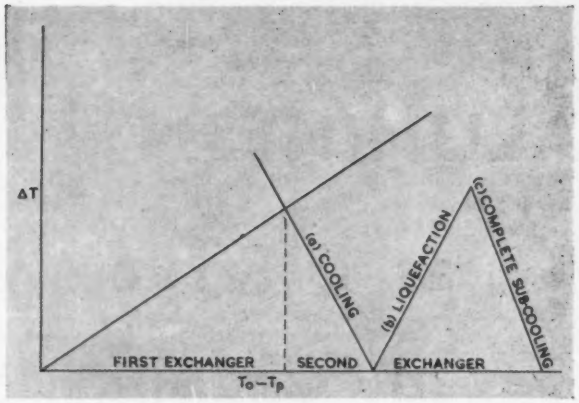


Fig. 5. Graph showing the most efficient condition for operation of expansion engine.

expansion engine is increased the amount of gas liquefied is also increased, since the differential coefficient is always positive.

When ε is small, the reverse variation is observed. This can be shown as follows. We have to consider the conditions of Fig. 3.

Let L_c be the latent heat of condensation of the compressed gas,

C_l be the specific heat of the liquefied gas,

T_s be the temperature at which the separated products enter the heat exchange system.

Then a heat balance on the heat exchanger in which liquefaction takes place gives

$$\varepsilon \left\{ C_l (T_l - T_s) + L_c + C_p (T_c - T_l) \right\} = y (T_p - T_s) C_p$$

$$yT_p = \varepsilon \frac{C_l}{C_p} (T_l - T_s) + \varepsilon \frac{L_c}{C_p} + \varepsilon (T_c - T_l) + y T_s \quad \text{.....(9)}$$

Combining equations (1) and (9),

$$T_c (1-\varepsilon) = \varepsilon \frac{C_l}{C_p} (T_l - T_s) + \varepsilon \frac{L_c}{C_p} - \varepsilon T_l + y T_s + T_o (1-y) \text{...(10)}$$

and eliminating T_c between equations (6) and (10)

$$\frac{KL}{\eta C_p (K-1)} = \frac{\varepsilon}{1-y} \frac{C_l}{C_p} (T_l - T_s) + \frac{\varepsilon}{1-y} \frac{L_c}{C_p} - \frac{\varepsilon T_l}{1-y} + \frac{1-y}{yT_s} + T_o \quad \text{.....(11)}$$

Hence on differentiating,

$$\frac{dy}{d\varepsilon} = \frac{d(1-y)}{d(1-\varepsilon)} = - \frac{\frac{C_l}{C_p} (T_l - T_s) + \frac{L_c}{C_p} - T_l}{\left[T_s + \varepsilon \left\{ \frac{C_l}{C_p} (T_l - T_s) + \frac{L_c}{C_p} - T_l \right\} \right] (1-y)}$$

The approximate evaluation of the quantity

$$\frac{C_l}{C_p} (T_l - T_s) + \frac{L_c}{C_p} - T_l$$

by the use of Trouton's rule shows that it is always positive. Hence the differential coefficient must always be negative, showing that when the liquefier is in the condition of Fig. 3, an increase in the amount of gas passing through the expansion engine produces a reduction in the amount of gas liquefied. By the separate application of these two deductions, it becomes clear that the maximum refrigeration performance is obtained when the exchangers are operating under the conditions of Fig. 5, where ΔT becomes zero at three points.

These main conclusions have been derived by the use of a number of simplifying assumptions. It only remains to examine how far the non-fulfilment of these assumptions in practice affects the validity of the conclusions. The most important of the assumptions are that we are dealing with ideal gases and with ideal heat exchangers of infinite area.

The deviation of real gases from the ideal gas laws affects the result in two ways. Firstly, the specific heats of the compressed and expanded gases are not in fact equal, and secondly the ideal isentropic expansion law is not in fact obeyed. Neither of these deviations affects the validity of the result. For the specific heat of the compressed gas is always greater than that of the expanded gas, so that the general shape of the heat exchange curves applies *even when there is no net liquefaction of gas.* And the deviation from equation (2), though it will affect the *value* of the differential coefficients obtained, will not affect their *sign;* and only the sign of the coefficients is used in the argument.

The use in practice of heat exchangers of finite area amounts to a shift of co-ordinates on Figs. 2-5, so that the temperature differences do not in fact become zero, but approach minimum values, which are the same in each case considered. This effect does not touch the validity of the argument, nor does the consequence that there is a heat loss, because of the imperfection of the heat exchangers, from the system which its refrigeration performance must supply. The effect of this additional heat load is merely to complicate the mathematics without affecting the sign of the differentials.

The other articles in this series will deal with the special conditions under which the distillation columns mentioned above have to operate and problems of gas purification, and a comparison between pre- and post-war practice will be given.

Wellcome Foundation Ltd's new factory at Dartford was opened by Sir Henry Dale on 27th April. The first things that strike one on entering this building are the excellent lighting, the unobtrusive arrangement of the services (including steam, compressed air, and de-ionised water) and the arrangements for space heating and ventilation. The building consists of two parallel single-storey wings, a layout which allows future extension in any desired lateral direction. The interior of the building, which will be used for the preparation, filling and inspection of pharmaceuticals, is similarly arranged to permit variation to production flow lines. The sterilising autoclaves, which in the ordinary way would have made the building uncomfortably warm, are neatly isolated in a thermal sense by the use of an air screen. The factor was designed by Waterhouse & Ripley and the consulting structural engineers were Bylander & Waddell.

ALUMINIUM

as a Structural Material for Chemical Engineering

E. ELLIOTT, A.Met., A.I.M.*

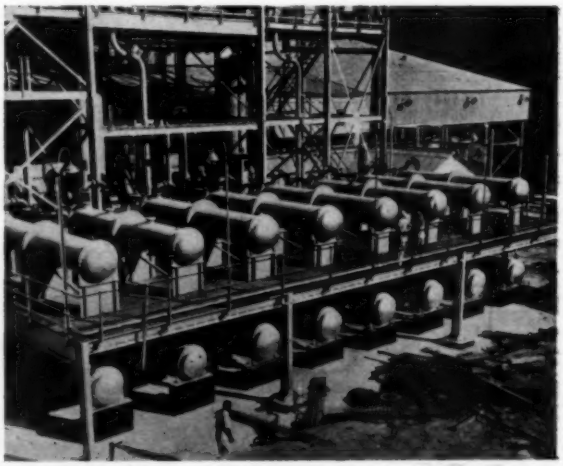
THE materials from which chemical engineering plant is made may be described as having a three-fold mission: to contain chemicals that wish to leave their vessels; to convey them where they do not desire to go; and to induce them to take part in reactions which they would rather avoid. For these reasons demands of the chemical engineer are very specialised, and the metals and alloys that he uses are many and varied. Although there are several virtues of aluminium and its alloys which commend them as materials for chemical plant, the most important of them is the high resistance to corrosion in numerous industrial environments.

Aluminium stands high in the electro-chemical series, and is active in many chemical reactions, so that at first sight it may seem strange to stress this property of resistance to attack by a variety of chemical agents. The reason for this corrosion-resistance is well known. A chemically inert and adherent skin of oxide is always present on the surface of the metal. Although this layer is only about 10^{-5} mm. thick, it provides great protection; moreover it is "self-healing" if damaged so long as oxygen is available. The composition and physical nature of this oxide layer is fairly complex and variable according to mode and temperature of formation, but its protective value is well established.

Other properties of aluminium are of interest to the chemical engineer, although each is individually less important than high resistance to corrosion. The specific gravity of the metal is about one-third of that of other metals such as steel and copper, which may prove important in the construction of large plant. Again, freight charges are reduced when chemicals are packed in aluminium containers.

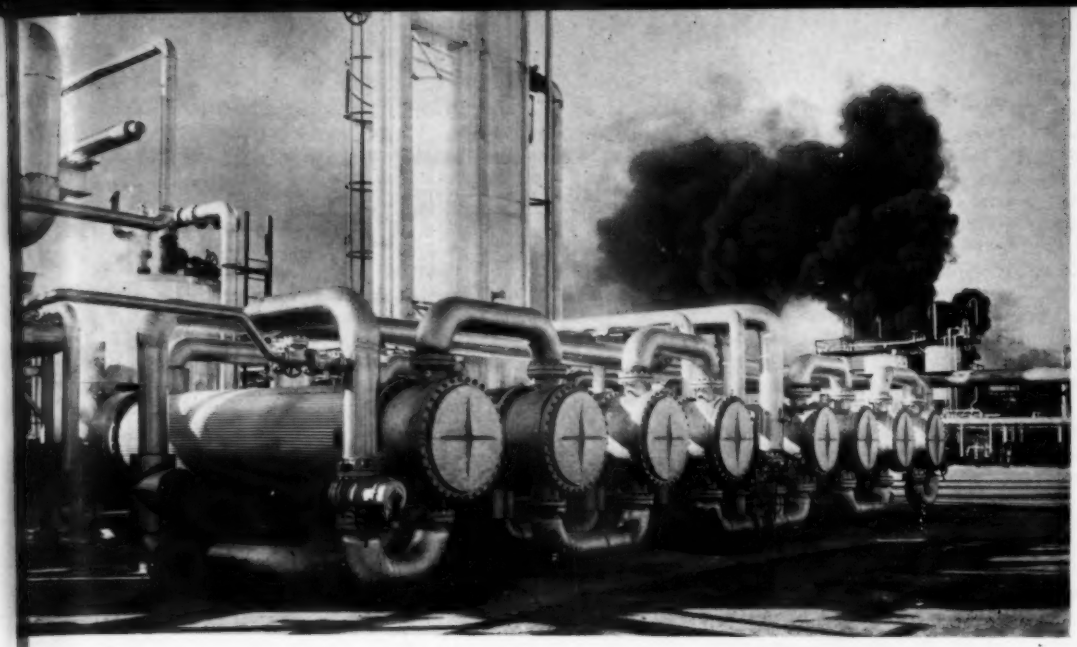
Aluminium has high thermal conductivity, which leads to its use in heat exchangers. It is suitable for equipment that has to be heated (e.g., such as boiling pans, sterilising plant and varnish kettles) or cooled (e.g., condenser tubes and refrigeration plant). Although aluminium conducts heat so well, the surface of the metal is highly reflective to radiant heat; this property results in the low absorption of heat from the sun by storage vessels, and reduces the losses caused by evaporation. It is this property which has led to the extensive application of corrugated aluminium as insulating covers (e.g., the lagging of pipes and tubes) and the use of aluminium foil for heat insulation.

Pulping tanks in the filtration plant of the gelatine factory of Treforest Chemical Co. Ltd; 99% aluminium, shielded arc welded.



A.P.V. aluminium carbonators installed at the ammonium sulphate plant at Sindri, near Calcutta.

* The Aluminium Development Association.



Heat exchangers incorporating aluminium alloy tubes manufactured by the Aluminum Company of America.

This metal is completely non-toxic, so that the preparation of substances for human consumption can be carried out in aluminium vessels with perfect safety; similarly, foods and pharmaceuticals are regularly packed in aluminium. The metal has no action on yeasts of bacteria involved in fermentation processes; hence its use in connection with the manufacture of citric acid and antibiotics. It has less effect than most other metals upon vitamins. Another advantage of aluminium is that when plant has eventually to be scrapped the metal commands a very high price, due to the ease with which it can be refined and re-used.

The strength and ductility of aluminium and its alloys are maintained or increased at sub-zero temperatures, a factor of great importance in many modern chemical processes.

These are the salient advantages of aluminium. Its relevant physical properties are given in Table 1.

Table 1. The Physical Properties of Aluminium.

Density: at 20°C (gm/c.c.)	2.70
Young's modulus (lb./in.^{2})	9.9×10^6
Torsion modulus (lb./in.^{2})	3.5×10^6
Poisson's ration	0.34
Compressibility: at 20°C (dv/v_o. dP)	1.45×10^{-6}
Coefficient of linear expansion (20-100°C)	24×10^{-6}
Thermal conductivity: at 0°C (cal./sec./cm^2/cm/°C)	0.50
at 100°C (cal./sec./cm^2/cm/°C)	0.51
at 200°C (cal./sec./cm^2/cm/°C)	0.51
Melting point	658 (°C)
Specific heat: at 20°C	0.214
at 100°C	0.223
Electrode potential at 25°C (volts) Solution potential at 20°C in millivolts (in aerated 2% NaCl solution against a normal calomel electrode)	-1.69 -740 to -750

A glance needs to be taken at the forms in which the metal is used, including the chemical compositions of standard grades of pure aluminium and alloys. British Standards cover the various wrought forms and also ingots and castings; the relevant numbers are BS 1470-77 and 1490, all of which were revised in 1955. The principal types of casting available are those produced in sand moulds, and by gravity and pressure diecasting; all the semi-tabulated wrought forms are readily available. Without doubt it is aluminium of 99.5% purity (i.e., Grade 1B) that has enjoyed the most widespread use in the chemical industry. However, there are certain alloys which, though perhaps not so highly corrosion-resistant as grade 1B aluminium, are broadly in the same class from the point of view of durability.

Four grades of pure aluminium are available: of these, the most pure grade, often referred to as "super-purity", is

Table 2. Typical Values for Ultimate Shear Stress.

Alloy	Form	Condition	Ultimate Shear Stress (tons/sq.in.)
1A	Sheet	O	4
		½H	4.5
		H	5
1C	Sheet	O	4.5
		¼H	5
		½H	5.5
		¾H	6
		H	6.5
	Extrusions	M	4.5
N4	Sheet	O	8
		½H	9
	Extrusions	M	8
N5	Sheet	O	9.5
		½H	11
	Extrusions	M	9.5
N6	Extrusions	M	11
H30	Extrusions	W	11.5
		WP	14

familiar to chemical engineers, who were the first to take advantage of its very high resistance to corrosion. As the degree of purity decreases, the strength increases; thus we find that aluminium of commercial purity (99% minimum) has the highest strength of the grades of pure aluminium. It needs to be mentioned that these grades, as well as the non-heat-treatable alloys of aluminium, are available in varying degrees of cold work, viz., quarter, half, three-quarter and fully hard (Table 2). (This remark only applies, of course, to wrought forms produced by cold working; extruded section are supplied only in the as-manufactured condition (M) with strengths similar to those of the annealed (O) condition.) The addition of 1¼% manganese gives, with little loss of ductility and even less of corrosion-resistance, an alloy with appreciably improved strength; this alloy, known as N3, is well worth the attention of the chemical engineer. Similarly magnesium may be added to form binary alloys containing 2½, 3½ and 5% Mg; these are designated N4, N5 and N6. These alloys are suitable in many environments, notably under chloride conditions, while those with lower contents of magnesium offer good all-round durability.

The above materials depend for their strength upon alloying and cold work. The other large class of aluminium alloys develop their properties on heat treatment. This involves solution treatment (W), which consists of heating to a temperature of roughly 500°C and quenching in water. Solution treatment may be followed by a further heating at about 200°C, giving an additional increase in strength; this is known as precipitation treatment, and the alloy is then said to be fully-heat-treated (WP). The principal heat-treated wrought alloys of interest in chemical works are those in which the alloying elements are magnesium and silicon; these alloys and the non-heat-treatable alloys are listed in Table 3. In general, the W condition offers the best corrosion resistance, while the WP gives the highest strength, together with durability adequate for many purposes.

In order to attain the best corrosion-resistance, items for chemical equipment are often cast in pure aluminium, which presents some difficulty in the foundry. Where better castability is important, and also where greater strength is needed, alloys may be used. Broadly speaking, the binary aluminium-magnesium and aluminium-silicon alloys have the best corrosion-resistance as cast, while the heat-treatable aluminium-silicon-magnesium alloys have similar durability with greater strength. The properties of the more important alloys are given in Table 4. Machinability is often an important property with castings; while the binary aluminium-silicon alloys may be machined efficiently with carbide-tipped tools, they are not so good in this respect as the aluminium-magnesium alloys. The extra strength and hardness of aluminium-silicon-magnesium alloys also improves their machinability, particularly if they are heat-treated. On the other hand, the pressure-tightness of aluminium-silicon and aluminium-silicon-magnesium alloys is very good, while aluminium-magnesium alloys are inclined to porosity; when pressure-tightness is essential, they can be sealed by a number of impregnation methods. Alloys containing silicon are the best choice when castings of intricate form have to be manufactured.

Table 3. Properties of Aluminium and the More Corrosion-Resistant Wrought Alloys.

(All figures are minima unless otherwise stated.)

Type	BS.1470	0.1% Proof Stress tons/sq. in.	Tensile Strength tons/sq. in.	Elogation % on 2 in.
99.99% Al	Sl-O	—	4.0 (max.)	45
	-H	—	6.5	6
99.8% Al	SlA-O	—	5.0 (max.)	35
	-H	—	8.0	5
99.5% Al	SlB-O	—	6.0 (max.)	30
	-H	—	8.5	5
99% Al	SlC-O	—	6.5 (max.)	30
	-H	—	9.0	3
Al-1¼ Mn	NS3-O	—	7.5 (max.)	30
	-H	—	11.5	3
Al-2½ Mg	NS4-O	—	11.0 to 14.0	18
	-½H	12.0	15.0	5
Al-3½ Mg	NS5-O	—	14.0	18
	½H	11.0	17.0	8
Al-5 Mg	NS6-O	—	17.0	18
	-½H	14.0	19.0	8
Al-Mg-Si	HS30-W	7.0	13.0	15
	-WP	16.0	19.0	8

Symbols: O=annealed, soft. H=hard. W=solution-treated. WP=fully heat-treated. Some of the above materials are also available in tempers other than those quoted. While the properties given are for sheet, those of other wrought forms are similar.

Table 4. Specified Properties of High Corrosion-Resistant Cast Aluminium Alloys.

(All figures are minima.)

Type	Designations (BS.1490)	Tensile Strength tons/sq. in.		Elongation per cent. on 2 in.	
		Sand Cast	Chill Cast	Sand Cast	Chill Cast
Aluminium-5% Magnesium	LM5-M	9.0	11.0	3	5
Aluminium-12% Silicon	LM6-M	10.5	12.0	5	7
Aluminium-5%	LM8-M	8.0	10.5	2	3
	LM8-W	10.5	15.0	2.5	5
Silicon-½%	LM8-P	9.5	12.0	1	2
Magnesium	LM8-WP	15.0	18.0	-	2
Aluminium-10% Magnesium	LM10-W	18.0	20.0	8	12

M=as cast. W=solution-treated. P=preciptation-treated. WP=fully heat-treated.

Working and Joining

After this rapid survey of the grades of pure metal and alloys of most interest to the chemical engineer, we turn to the manipulations which are necessary in plant manufacture. No special problems arise in bending and forming but the application of heat for forming is obviously limited to non - heat - treatable materials and needs careful control. Full details of pressing, drawing, spinning, bending and similar operations have been published (e.g. in the ADA Information Bulletins). The cutting of aluminium or its alloys presents no special difficulties, and methods of cutting using welding equipment are in an advanced stage of development. Reference has already been made to the relative machinability of aluminium casting alloys; with the wrought metal and alloys the softer materials tend to drag somewhat on machining, and care is required to obtain a good finish, whereas

the harder alloys are readily machined. It is in the field of joining that the most impressive recent advances have taken place in recent years. The technique of driving small rivets in aluminium and its alloys is long established; during recent years, it has been extended to rivets up to 1 in. diameter, so that very large riveted joints may be made, both in the workshop and in the field. These large rivets are covered by BS 1974 (1953).

The fusion-welding of aluminium used to present great problems but these have now been solved. The early work on gas-welding of aluminium was, of course, largely done in connection with chemical equipment, and aluminium vessels have been successfully welded for many years by the oxy-gas flame. There is one serious drawback here; the fluxes used are severely corrosive, and their residues must be scrupulously removed from the metal after welding. This affects design; joints must be so located that this post-weld treatment is facilitated, while lap-welds represent a danger of flux-entrapment, which may cause corrosion later in the life of equipment. Furthermore, although the gas welding of pure aluminium is readily learnt by the welder, certain of the alloys require a considerable measure of special skill; this applies particularly to the alloys containing appreciable contents of magnesium or magnesium and silicon. The heat-affected softened zone in work-hardened or heat-treated material is more extensive with gas-welding than with the more modern methods.

Metal-arc welding with coated electrodes is also used with aluminium and its alloys, and some authorities believe that this process will develop very considerably in the future. Flux residues are again a problem, but with certain electrodes it is claimed that they may be left *in situ* without danger. The types of welding most effective for chemical plant are those which depend upon a shroud of inert gas, and obviate the necessity for flux. Two principal types are widely used. The first is inert gas-shielded tungsten arc welding, which employs a tungsten or tungsten alloy electrode; the filler rod, where necessary, is fed in separately. In the second type, or inert gas-shielded metal-arc welding, the filler wire is automatically fed through the argon shroud, and acts as the electrode. Reference is made to argon because that gas is invariably used in this country, while in America helium is used for some applications. Of the two processes the first is at present the more attractive to the chemical engineer, because it provides very sound welds with little danger of sub-surface cavities.

With inert gas-shielded arc welding of non-heat-treatable materials, filler rods are usually of the same composition as the metal being welded, as there is little loss of alloying elements. Pure aluminium, the aluminium-manganese and aluminium-magnesium alloys are all very efficiently joined by this method. When work-hardened material is welded, there is some softening in the heat-affected zone, but the zone is narrow and welding is so rapid that good strengths are attained. The heat-treatable alloys present greater problems. Autogenous welding of the aluminium-magnesium-silicon alloys is used, but requires precaution to avoid weld cracking if any restraint is present. Aluminium 5% silicon is often used for the filler rod (NG21 in BS 1475). In either case, the weld strength is below that of the parent metal, unless re-heat-treatment can be applied.

Inert gas-shielded arc welding is applicable to the joining of castings, and also of castings to wrought material. This may often be of value in chemical equipment as, for instance, in connecting cocks to vessels and in attaching tubes to cast flanges; similarly valves may be incorporated in pipe lines by this method.

The electrical and other conditions for both types of welding are the subject of a voluminous literature. Table 5 summarises the salient details of welding conditions and speed; and Table 6 shows the effect of the composition of the filler rod on the mechanical properties of welded aluminium-magnesium alloy.

Aluminium brazing using aluminium-silicon filler alloys is particularly useful where temperature of joining must be kept as low as possible and distortion at a minimum. As with welding, brazing may be used for wrought or cast materials, or joining the one to the other. This last is a relatively new development, and deserves the attention of designers as do the possible uses of the new hard soldering techniques.

Table 6. Effect of Filler Rod Composition on Strength of Weld. Type of Weld: Butt joint between $\frac{1}{2}$ in. thick plates (Al+5% Mg)

Filler Rod	0.1% Proof* Stress		Tensile*		Elongation* % on 2 in.
	tons/sq.in.	kg/sq. mm	tons/sq. in.	kg/sq. mm	
Pure Aluminium	6.5	10.2	15.05	23.7	19
Al+2% Mg	5.9	9.3	16.6	26.1	20.5
Al+3½% Mg	6.7	10.6	16.2	25.5	21.5
Al+5% Mg	6.4	10.1	16.5	26.0	21.0
Al+7% Mg	6.5	10.2	17.4	27.4	30
Al+5% Si	6.0	9.4	14.4	22.7	11
Parent metal	6.8	10.7	17.2	27.1	33

*These results are the average of six tests.

Other Design Features

Design has, of course, a most important part to play in ensuring that aluminium chemical plant presents the best resistance to corrosive attack. The avoidance of crevices is imperative, and good welds correctly finished are particularly vital in this respect. Vessels

Table 5. Average Working Conditions for the Automatic A.C. Argon-arc Welding of Aluminium and its Alloys.

Thickness of Parent Metal in inches	Edge Preparation	No. of Passes	Welding Current (amp)	Electrode Diameter (in.)	Filler Rod Diameter (in.)	Argon Flow (cu. ft./hr)	Welding Speed (in./min)
0.04	Flanged, close	1	73-120	$\frac{1}{8}$	—	10-12	40-110
0.06	Square, close	1	100-200	$\frac{1}{8}$ or $\frac{5}{32}$	—	12-16	40-100
$\frac{1}{8}$	Square, close	1	130-530	$\frac{5}{32}$ or $\frac{1}{2}$	—	14-18	20-60
$\frac{5}{32}$	Square, close	1	200-400	$\frac{5}{32}$ or $\frac{1}{2}$	—	16-20	20-50
$\frac{1}{4}$	Square, open or 90 deg. bevel, close	1	500-300	$\frac{5}{32}$, $\frac{1}{4}$ or $\frac{5}{16}$	$\frac{1}{8}$-$\frac{5}{32}$*	16-20	10-23

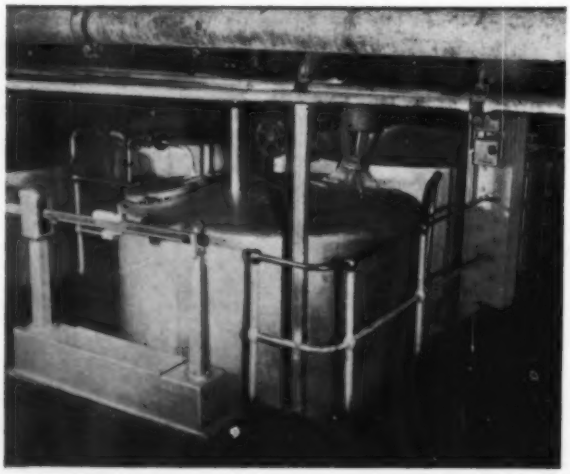
*Feeding at 10-20 in./min.

should be so constructed that when emptied their contents are completely discharged, and the inside easily accessible for cleaning. As already noted, aluminium stands high in the electro-chemical series, and it is therefore particularly susceptible to bi-metallic corrosion when joined to more noble metals. Copper and its alloys constitute a particular danger, and cannot be associated with aluminium equipment. Plain carbon steels or iron are less dangerous, but they can cause attack under aggressive conditions and are best avoided. Zinc is without effect; zinc-coated steel and cadmium plate are satisfactory so long as the coatings endure. An all-aluminium system is the most desirable, since metals such as copper may be taken up by a liquid and deposited on aluminium to act as centres of electrolytic corrosion. Mercury from broken mercury-in-glass thermometers is a menace.

As is fairly widely recognised, the distance between two metals in the series of electrolytic potentials is not necessarily a measure of the danger of bi-metallic corrosion when they are in contact. Thus lead may often be safe with aluminium, and austenitic stainless steels cause no trouble in mild conditions. Each case of contact must be treated on its merits and in the light of experience.

Several methods of protecting aluminium have been perfected. Anodising is well-known; this thickens the naturally occurring oxide film and considerably increases the metal's resistance to attack by many media. It has been conclusively shown that paints last much longer on correctly pre-treated aluminium alloys than on other structural metals—an important factor in chemical works. An indirect method of protection depends on the addition to liquors of small proportions of inhibitors; examples are the use of soluble chromates in certain aggressive waters; and sodium silicate in alkali carbonate solutions. Soluble oils, sugars, gums and many other substances are also used as inhibitors.

The cleaning of aluminium chemical equipment should not present any special difficulties. Proprietary detergents based on inhibited sodium carbonates can be used, while many of the modern synthetic detergents are perfectly satisfactory with aluminium. The removal of deposited "stones" is a greater problem, but proprietary compounds exist which can be used to loosen the deposits without adversely affecting the metal.



Tanks of aluminium —1½% manganese alloy for blending fatty acids. These tanks and pipes were in a perfect condition after 10 years' service. Photo by courtesy, British Aluminium Co. Ltd. and Thomas Hedley & Co. Ltd.

Table 7. Effect of Temperature on Mechanical Properties of Cast Alloys.

Material	Property*	Temperature (°C) 20	100	150	200	250	300	350	400
LM5-M	PS	5.3	5.3	5.4	6.2	6.3	4.2	2.8	1.9
	TS	9.5	9.8	10.5	9.7	8.5	6.1	4.1	2.5
	El	4.5	5.0	8.3	5.5	7.5	8.0	8.0	8.5
	BHN	63.9	57.2	53.8	52.8	41.5	28.7	17.0	11.5
LM6-M	PS	4.5	4.3	3.8	3.4	2.7	1.9	1.5	1.1
	TS	11.9	10.0	8.4	6.8	5.0	3.8	2.7	2.0
	El	12.5	12.0	12.0	17.5	17.5	18.0	21.5	27.0
	BHN	55.8	51.2	43.1	36.8	28.1	20.2	12.8	7.5
LM8-W	PS	8.1	8.4	8.8	13.5	9.0	4.1	1.9	
	TS	13.7	13.5	12.5	15.3	10.2	4.7	2.3	
	El	3.0	3.9	2.8	1.9	2.2	10.0	29.0	
	BHN	71.6	64.6	58.3	56.8	34.8	19.6	10.5	6.1
-WP	PS	14.0	13.4	12.8	11.6	9.8	4.5	2.5	1.2
	TS	16.7	16.0	14.7	13.6	10.6	5.4	3.3	1.9
	El	0.8	1.2	1.3	1.4	1.0	7.0	19.0	65.0
	BHN	95.1	80.2	75.6	58.3	37.5	18.2	9.9	5.8
LM10-W	PS	14.5	10.8	10.6	10.0	5.8	2.7	2.0	0.9
	TS	20.9	17.2	16.4	14.4	11.6	7.0	4.4	3.2
	El	5.1	8.6	10.1	6.3	9.0	22.3	39.2	63.4
	BHN	82.3	76.2	73.0	65.1	45.2	25.5	15.6	9.6

Table 8. Effect of Temperature on Mechanical Properties of Wrought Alloys

Material	Property*	Temperature (°C) 20	25	100	150	200	250	260	300	315	350	370	400
1C-O	TS	6.0		3.3	2.7	1.5			1.1		0.6		
	El	45		65	70	85			90		95		
-½H	TS	7.6		6.0	4.2	1.5			1.1		0.6		
	El	20		22	25	85			90		95		
-H	TS	10.7		7.8	2.7	1.5			1.1		0.6		
	El	15		16	70	85			90		95		
N4-O	TS	13.0			8.0			3.25					
-½H	TS	18.5			11.0			3.6					

*PS=0.1% proof stress (tons solidus sq. in.). TS=tensile strength (tons/sq. in.). El=elongation (% on 2 in. specimen). BHN=Brinel Hardness Number.

Recent Developments

While the use of aluminium alloys for structures in chemical works is not new, it has extended during the past few years, notably where the presence of products of combustion of sulphur results in rapid attack of other structural materials. Aluminium alloy roofs and siding are giving very good service, for instance, in gas works. At one very large chemical works it has been found that, even under the most unfavourable conditions, a bare aluminium roofing sheet will give nearly four times the life of galvanised steel. The same investigations confirmed the excellence of aluminium as a base for paint; thus in areas where steel is found to require repainting at least once a year, painted aluminium alloys show little deterioration after four years.

Mention has already been made of super-purity aluminium; although work-hardened material is available, annealed metal is almost lead-like in character, a property which is useful where extensive working is necessary but restrict the use of the metal to applications where strength is not important. To overcome this disability, a series of alloys has been developed, principally with magnesium or with magnesium and silicon. These materials, developed mainly for non-chemical uses, deserve the attention of the designers of chemical equipment. Super-purity

These 1,750-gallon argon-arc welded tanks are used in the manufacture of hydroquinone. Photo: May & Baker Ltd.

aluminium is also being used as a protective cladding for aluminium alloy sheet and plate, and these composite materials are useful in certain special applications.

One of the drawbacks of aluminium and many of its alloys is that their strength falls rather rapidly as temperature increases (Table 7 and 8). Alloys containing nickel are the best in this respect, and offer useful properties at temperatures as high as 300/350°C. A relatively new material giving better high temperature strength is a product of powder metallurgy, namely sintered aluminium powder (SAP), which is now available in this country as sheet, bar, sections, tubes and stampings. This material retains its properties as temperature increases. The method of production of this material is patented by a Swiss company, but an English firm is licensed to produce it in all forms. It has been shown that it is the high content of aluminium oxide (10-15%) in the compact that confers the resistance to high temperature, and prolonged cycles of soaking at 500°C do not affect the room-temperature properties of the material. The corrosion resistance of SAP is similar to that of pure aluminium, and anodising may be applied to it. An additional point of importance is that the material can be hard-anodised to give thick abrasion-resistant oxide films.

In many processes, it may be valuable to have tube or sheet with aluminium on one side, and another metal on the other, thus having the best of both worlds. Composite aluminium/steel tubes may now be obtained, with either metal on the outside, and similarly copper/aluminium sheets are available. It goes without saying that these combined metals can represent a considerable corrosion hazard at edges if care is not taken in design and installation. Mention of aluminium with steel leads to the use of aluminium as a corrosion-protective for steel; sprayed aluminium is well known and already has many applications in the chemical industry. A recent extension of this is showing much promise; certain plastics coatings on chemical tanks, while giving excellent protection, tend to become detached; if applied over a coating of sprayed aluminium, however, adhesion is much improved.

Although aluminium has been used overseas for some time as a protective coating for steel, applied by hot-dipping, it is only very recently that hot-dip aluminising has been applied commercially in this country. An aluminium-silicon alloy is often used; the value of the silicon content is that it minimises the alloy layer formed at the junction of the two metals, and also renders it softer and less brittle; for thin coatings, however, pure aluminium is quite suitable. Some forming may be applied to aluminised steel sheet, although it is not quite so tolerant of deformation as a galvanised coating. The resistance to corrosion is excellent, especially where the metal meets industrially polluted atmospheres.

Very recently investigations have been made of the scaling resistance of hot-dip aluminised steel, which showed that the coating provided effective protection at temperatures up to 800°C; coatings containing silicon proved to be somewhat less heat-resistant than those of commercial aluminium alone. The gains in weight recorded were, in general, less than those gained by heat-treated sprayed aluminium coatings, and Erichsen tests after exposure to temperature for 2,000 hours revealed no flaking of the coating.

Most of the experiments on hot-dip aluminising have been with steel, and cast-iron presents rather greater difficulties in the coating process. However, small grey-iron castings have been successfully treated, and work is proceeding on this aspect.

One considerable problem with aluminium is that it may suffer from pitting when in contact with certain waters, if the temperature is low and the water is static or slow-moving. Research in this country and the U.S.A. has shown that a high measure of protection is given by cladding a suitable alloy with another, just sufficiently anodic to it, an aluminium —1% zinc alloy on aluminium —1¼% manganese being a good combination. Methods of making duplex tubes have been developed, and service trials are in train. While aluminium and its alloys often give very good service under conditions of corrosion and mild abrasion, heavy abrasion often results in serious attrition. Hard chromium plating is sometimes a solution, and much interest has been created by the recent development of hard anodising.

In this process, the anodising conditions are modified to give coatings as thick as 0.002 in. or more. Refrigeration of the anodising bath is involved, and costs are quite high, but are often justified in view of the abrasion resistance provided. On pure aluminium, hardness values as high as 500 VPN are attained, and abrasion tests with a Tabor abrasion tester for 50,000 cycles of abrasion gave wear on a hard anodised coating a little less than half that on cyanide case hardened steel. So far as may be ascertained from the literature, hard anodised coatings have hitherto found little application in chemical equipment.

SELECTED READING LIST

Books. "Aluminium in the Chemical and Food Industries." British Aluminium Co. Ltd., 1951, pp. 149.

"Aluminium with Food and Chemicals." Northern Aluminium Co. Ltd., 1955, pp. 90.

"Das Chemische Verhalten von Aluminium" Aluminium-Verlag G.m.b.H., Düsseldorf, 1955, pp. 333.

"Aluminium and Aluminium Alloys in the Food Industry." Special Report No. 50, Food Investigation, D.S.I.R., H.M.S.O., 1948, pp. 153.

"Aluminum in the Chemical Industry." Aluminum Company of America, Pittsburgh, 1946, pp. 78.

The Information Bulletins of the Aluminium Development Association, London.

Papers and Articles. Clark, W. D., "Atmospheric Corrosion of Aluminium Alloys in a Large Chemical Factory and Their Protection by Painting," *J. Inst. Met.*, 1955, **84**, 33-41.

Nuttall, R. W., "Aluminium in the Food and Chemical Industries," *Metallurgia*, 1954, **49**, 63-70.

Hughes, M. L., "Hot-Dip Aluminized Steel, Its Preparation, Properties and Uses," *Metal Finishing Journal*, 1955, **1**, 447-450, 452.

Lawrence, S. M., "Aluminium and its Alloys in the Chemical and Processing Industries," *Industrial Chemist*, 1951, **27**, 219-224.

Lees, D. C. G., "Aluminium and its Alloys (Non-Ferrous Metals in Chemical Engineering)," *Metal Industry*, 1953, **83**, 190-191.

Fritts, H. W., "Aluminum Alloys (in Chemical Engineering)," *Ind. Eng. Chem.*, 1953, **45**, 2175-2182.

Brace, A. W., "Hard Anodising of Aluminium and its Alloys," *Electroplating and Metal Finishing*, 1954, **7**, 329-334, 376-379.

Irmann, R., "Sintered Aluminium with High Resistance to Heat," *Revue de l'Aluminium*, 1951, **28**, 269-275, 311-316.

REINFORCED PLASTICS

Show great promise for corrosion-resistance applications

by R. BENNETT*

MOST thermosetting plastics are inherently brittle and of rather low strength. On the other hand their corrosion resistance is excellent, they can withstand use at relatively high temperatures and their density is low. In recent years these plastics reinforced with glass or asbestos fibres have been widely used for structural purposes, such as the manufacture of motor-car bodies and boat hulls. The combination produces a tough, rigid, impact-resistant structural material, which has the advantage that it can be simply and cheaply fabricated into complex forms.

So far reinforced plastics have not been applied extensively in chemical plant construction, although they should show advantages in some applications. There are two reasons for this delay on the part of the chemical engineer: little design information is available, particularly on the corrosion-resistance of the composite material, and the simple "no-pressure" fabrication methods, which have been commonly employed, produced an inconsistent product. It is only in the past few years that the importance of factors other than the choice of resin, reinforcement and filler has been fully appreciated. These additional factors include surface treatment, amount and physical form of the reinforcement; design of the article to be constructed; fabrication method; and the quantity of air and moisture vapour trapped in the product.

Choice of Resins

Five basic types of organic resin are used to make reinforced plastics structures: polyesters, phenolics, epoxides, silicones and furanes. By far the most popular resins for general constructional work are the polyesters. The strength of a polyester resin-bonded glass laminate compares favourably with that of aluminium or stainless steel, with the added advantage of a lower density.

The polyester resins have a number of advantages, including low-temperature and low-pressure curing, which make them particularly suitable for use with simple fabricating methods. A remarkably wide range of properties can be obtained by suitable choice of resin and catalyst. Special polyester resins with good resistance to chemicals are available commercially, and also flame-retardant grades.

The phenolic resins have the advantage of cheapness and better chemical resistance than the chemical grade polyesters in most applications. In particular, the phenolics show excellent resistance to most organic liquids at temperatures up to 100°C. They are also more resistant to sulphuric acid and can be used in concentrations up to 70%. They are only resistant to nitric acid in dilute solutions. Phenolics have a good working life at temperatures as high as 180°C—much higher than other common laminating resins. Their main disadvantage is the need for pressure and, in addition, heat treatment to secure a satisfactory cure. This rules out some of the simpler fabrication techniques.

Epoxy resins have a number of properties which commend them as laminating resins including good corrosion resistance, high strength and good adhesion to reinforcement. Furane resins also have useful properties for laminates for the chemical industry but as they are in an early stage of development they are not yet being used extensively.

Because of their outstanding resistance to temperature, silicone resins have been used to make laminates for certain special applications and will withstand temperatures up to 250°C. They have good chemical resistance, low water absorption and excellent electrical properties but are rather expensive.

Reinforcement and Filler

The glass fibres used in reinforced plastics are either of the borosilicate type, with an alkali content of less than 1%, or the soda glass type with an alkali content of 8-15%. The individual fibres, which are only a few microns in thickness, have extremely high tensile strengths—much higher than that for glass in bulk. Tensile strengths of the order of 200 kg/sq. mm are quite common. As the resin in which the fibres are embedded does not protect the glass completely from chemical attack, it is important that corrosion resistance of the glass reinforcement be also considered.

Asbestos reinforced laminates compare in strength with glass reinforcements and when surface coated with Furane can be resistant to moderate alkali concentrations.

The asbestos laminates are, however, less strong and have poorer impact resistance than those made with glass fibres. For chemical applications, where corrosion problems may be severe, it is probably inadvisable to use asbestos fibres as reinforcing material, although asbestos has been used successfully as a reinforcement for furane resins.

* Thermo-Plastics Ltd.

Table 1. Chemical Resistance and Physical Characteristics of Epikote Resin Glass Cloth Laminates

The table below was compiled from experimental data on Epikote 828-181 Volan A Fibreglass laminates. Cure was effected by metaphenylenediamine at a pressure of 200 psi by heating to 300°F for about 30 minutes followed by one hour at 400°F. The resin content of the various test pieces was 25-35% by weight; the initial flexural strength varied between 68,000 and 79,000 psi at room temperature, and 44,000 to 49,000 psi at 300°F.

CHANGES IN WEIGHT AND FLEXURAL STRENGTH AFTER IMMERSION IN VARIOUS CHEMICALS.

Chemical	% Wt. Increase Immersion Time. Days				Flexural Strength psi Immersion Time. Days			Flexural Modulus after 90 days Immersion. psi x 10^6
	7	30	90	180	90	180	360	
Water, distilled	0.17	0.31	0.99	0.67	70,450		71,000	3.00
ACIDS								
Sulphuric acid, 3%							48,000	
Sulphuric, 95%	delaminated						—	
Sulphuric, 70%	0.11	0.20	0.26	0.34	73,150		71,000	3.03
Hydrochloric, 37%	0.01	−0.21	−0.89	−5.7	54,700	40,200	39,300	2.57
Hydrochloric, 10%	0.04	0.00	−0.09	−0.32	65,000		50,000	2.89
Nitric, 50%	Top layer delaminated							
Nitric, 30%	0.05	−0.21	−1.73	−4.8	41,950	13,700	5,000	1.92
Phosphoric, 98%	0.01	0.10	0.34	0.74	69,550		67,000	2.75
Phosphoric, 64%	0.09	0.18	0.32		73,300		55,900	3.40
Phosphoric, 43%	0.11	0.25	0.43		77,700		63,600	2.90
Phosphoric, 21%	0.12	0.25	0.45		67,180			3.00
Phosphoric, 10%	0.15	0.27	0.40	0.54	70,000		66,700	3.11
Phosphoric, 4.25%	0.12	0.23	0.60		70,480		66,500	2.80
Acetic glacial	0.12	0.34	0.41	0.42	77,000		65,000	3.31
Acetic, 10%	0.15	0.29	0.41	0.62	71,000		61,000	3.14
Oxalic saturated	0.05	0.24	0.76	2.5	55,400	43,000	disintegrated	2.38
ALKALIES								
Sodium Hydroxide, 50%	0.01	−0.23	−0.75	−1.3	71,900	66,900		
Sodium Hydroxide, 1%	0.12	0.17	0.24	0.36	67,300		64,000	2.25
Ammonium Hydroxide, 28%	0.24						40,660	3.18
Ammonium Hydroxide, 10%	0.13						33,630	
SALTS								
Sodium Chloride, 20%	0.13	0.24	0.38	0.40	67,950		69,000	3.20
Sodium Sulphate, 30%	0.12	0.24	0.41	0.64	66,950		67,000	2.95
Etching Solution*	0.17	−0.96	−2.79		51,750			2.46
Copper Plating Solution†	0.04	−0.04	−0.17	−0.34	63,300		53,000	3.08
ORGANIC SOLVENTS								
Acetone	0.29	0.33	0.52	1.0	70,250	52,970	43,900	2.84
Tthyl Acetate	0.26	0.45	—	0.45			65,000	
Ethylene dichloride	0.13	0.35	0.57	0.59	69,350		66,000	2.81
Ethylene glycol	0.04	−0.03	−0.03	−0.23	77,750		70,000	3.28
Buty; Cellosolve	0.04	−0.02	−0.01	−0.13	73,100		68,000	2.94
Methyl Carbitol	0.09	0.25	0.43	0.34	78,250		74,000	3.19
Hydraulic brake fluid	0.09	0.18	0.30	0.40	73,400		65,000	3.11
Jet fuel	0.02	0.08	0.15	0.14	71,850		65,000	3.25
Octane Gasoline 108	0.01	0.07	0.13	0.12	69,900		66,000	3.04
Methyl Ethyl Ketone	0.05	0.24	0.28				72,700	
Diacetone Alcohol	0.02	0.02	0.04				69,500	
Hexylene Glycol	0.00	−0.01	−0.01				70,400	
Isopropyl Alcohol	0.01	−0.02	0.04				65,720	
Sec-Butyl Alcohol	0.01	−0.03	0.00				74,600	
Trichloro propane	0.00	0.17	0.27				68,660	
CHEMICAL INTERMEDIATES								
Allyl Chloride	0.05	0.08	0.15				69,400	
Epichlorhydrin	0.00	0.35	0.51				64,800	
Allyl Alcohol	0.20						54,330	
Phenol							disintegrated	

*Etching Solution—10 parts sodium dichromate; 50 parts 96% sulphuric acid; 300 parts distilled water.

†Copper Plating Solution—29.5 parts copper sulphate; 13.5 parts 95% Sulphuric Acid; 300 parts distilled H_2O.

The Glass-Resin Interface

The natural advantage of asbestos, cotton, paper and other laminating materials in offering a mechanical key between reinforcement and resin does not apply to the smooth-surfaced glass fibres. Adhesion between glass and resin must therefore be obtained by chemical means. After heat cleaning to remove textile size applied during manufacture, the glass is coated with a Silane or Volan compound which provides a strong polar bond with the glass and a suitable non-polar surface compatible with the resin.

In spite of the surface treatment, perfect adhesion between glass and resin has not been achieved and surface treatments are still the subject of research work. Unless good adhesion is obtained between the two components, the working load is not efficiently transferred from resin to glass and vice versa. As the resin cures it contracts and may pull away from the glass fibre leaving a capillary void, but this can be largely obviated by the use of the aforementioned treatment of glass. If a laminate with poor adhesion is used in contact with liquids, capillary attraction will draw liquid into the voids where it reacts with the glass fibre and destroys the laminate.

Application of Reinforcement

The glass fibre reinforcement may be used in a number of different forms: as roving, woven cloth, woven roving, or mat. The roving consists of a bundle of continuous filament yarn with the filaments roughly parallel to one another. The mechanical properties of the laminate depend on the manner in which the rovings have been placed. The strength is very high in the direction in which the roving lies. Advantage of this method of construction is taken in many applications where the principle stress directions are known; for example, tubing to withstand high internal pressures may be made by helical winding of rovings.

Woven glass cloth reinforcement gives laminates of good strength particularly if the weave is directional. The mechanical properties do not however compare with continuous rovings, as the high angles of crimp automatically give rise to lower tensile strengths. Woven roving, a loosely woven cloth made from roving, is extremely useful where high bulk and good impact strength are required.

Where strength is not of prime importance, glass mat is the cheapest form of reinforcement to use. Laminates are built up quickly by use of mat. This type of laminate has

Table 2. Chemical Resistance of a Typical Polyester Glass-cloth Laminate

Reagent	Result after Short Period of Contact		Result after Contact for 3 months	
	Room Temp.	50°C	Room Temp.	50°C
Sulphuric acid, 25%	O	—	—	...
Chromic acid, 25%	O	—	—	...
Hydrochloric acid, 25%	O	O	O	--
Nitric acid, 25% ...	O	O	O	—
Ammonia solution, 25%	—	—	...	...
Sodium hydroxide, 10%	—	—	..	...
Sodium hypochlorite 2%	O	O	O	O
Sodium carbonate, 25%	O	O	O	—
Formalin	+	O	O	O
Cresol	+	—	+	...
Tricresyl phosphate ...	+	+	+	+
Trichlorethylene ...	O	...	O	...
Ethylene glycol ...	+	+	O	+
Benzene	+	...	+	...
Petrol	+	...	+	...
Acetone	--	...	...	...
Crude oil	+	O	O	O
5% Detergent solution	O	O	O	O
Sea water	O	O	O	O
Tap water	O	O	O	O

\+ Resistance Satisfactory
O Limited Service.
— Unsatisfactory.

The laminates tested were produced using 0.009 in. heat-cleaned glass fabric and a heat-resistant polyester with good electrical properties.

Table 3. Comparison of Manufacturing Methods

Method	Cost	Product	Special features
Single Mould Methods			
LAY-UP Uses a single mould (male or female) on which impregnated reinforcement is applied and allowed to cure at ambient or elevated temperatures. *Mould* — plaster wood, aluminium or reinforced plastics.	Moderate tool and labour costs. Slow cycle.	Difficult to achieve optimum physical characteristics and dimensional accuracy.	Inexpensive for prototype work. Ideal method for large structures.
VACUUM BAG Uses single female mould on which resin and glass are laid-up followed by pressure from rubber vacuum bag. *Mould*—wood, aluminium or reinforced plastics.	Moderate tool and labour costs. Slow cycle.	Usually used where cure and elevated temperatures are required. Product is reasonably consistent.	A more satisfactory method for small numbers of parts.
PRESSURE BAG As for vacuum bag, but higher pressures imparted by bag brought into contact with laid-up resins. *Mould* — Aluminium, steel.	Moderate labour costs. Faster cycle.	Good physical properties. Consistent results.	The best single mould method for moderate production runs.
Matched Mould Methods			
MATCHED DIE The dies are loaded with glass reinforcement, filled with resin and pressure applied. *Moulds*—Steel.	High tool costs. Low labour costs. Rapid cycle.	Very good consistency optimum physical properties.	The only method advisable for laminates where a rapid rate of production is required.

Table 4. Physical Properties of a Typical Polyester Resin Bonded Glass Laminate

Tensile Strength	40,000 psi
Specific Gravity	1.7
Modulus of Elasticity in Tension	Approximately 2.8 x 10^6 psi
Thermal Conductivity ...	2-3 BTU in. sq. ft/ft hr/°F
Impact Strength (edge unnotched) ft. lb.-in. ...	22
Flexural Strength	48,000 psi
Linear Coefficient of Expansion	6 x 10^{-6} /°F

Where cloth reinforcement is used, the laminate is built up by hand lay-up of alternate layers of resin and cloth. Each layer of cloth is rolled down to remove air bubbles and ensure good wetting out of the cloth by the resin. Cloth is cut to the required shape and size before impregnation with resin.

good physical characteristics, which are about 20% lower than those of comparable cloth laminate.

Where articles are mass produced the glass reinforcement is often pre-formed to the appropriate shape by a felting technique. Chopped glass-fibre strands about 2 in. long are drawn by an air stream into a plenum chamber and deflected on to a perforated metal screen of the same shape as the part to be moulded. When the screen is uniformly coated with fibres, the glass reinforcement is removed for impregnation with resin.

Fabricating Methods

Early attempts at making laminates were by very primitive methods which resulted in a very inconsistent product. These early methods have been largely superceded by the introduction of more modern techniques and the exercise of greater control.

A summary of the various fabricating methods is given in Table 3. As the matched die method involves high tool costs and low unit labour costs it can only be used economically for parts which are required in fair numbers. In consequence it is best suited to products which can be built up out of a number of identical units. Thus, tank units are available in this country and the United States; filter press plates, chimney stack units, and dryer trays have also been made.

One factor which is often forgotten is that the moisture content of laminates is important and special steps must be taken to control it during manufacture if the best results are to be obtained.

Designing for Reinforced Plastics

The process of producing laminated plastics can in some ways be regarded as a casting operation, although the matter is complicated by the presence of the solid reinforcing material. The design procedure for laminated resin parts has much in common with that for castings. Due allowance must be made for shrinkage, the design should be fairly simple, generous radii should be allowed and the tolerances should be reasonable. Back draft and undercuts should be avoided and the draft angle should be fairly large. The wall thickness should be constant, or if changes are necessary, they should be gradual.

The greatest possible use should be made of the flexibility of the fabricating method to make a single part combine several functions. For example stiffening ribs may be moulded integrally with the part to be stiffened. Use should also be made of the special structural properties which may be imparted by use of glass roving. It may, for example, be possible to lighten a particular part by giving it exceptional strength in those places and directions where it is known large stresses occur.

Does it Pay to Use Laminates?

Plastic laminates are not cheap. Glass fibre is an expensive structural material costing about 4s. 9d. a pound. Resins are also fairly expensive. The price of laminates is thus three or more times that of steel and this high price will clearly limit its applications. Whether or not a reinforced plastic pays its way in the chemical industry depends very much on how its price and life compare with alternative materials. It will also depend on the relative cost of making the part in laminate and alternative materials. In many cases, where the object to be made is complex, the cost of fabrication in laminate is a great deal lower than that of making it in metal. Sometimes the low density and high strength/weight ratio of resin laminates may tell in their favour. For example, considerable savings may be made in the cost of supports for fume ducting by using resin laminates.

In the end, however, the main question will almost certainly be that of corrosion resistance and, in the absence of detailed information, the best thing is to try it and see. In the first place a small sample of resin laminate should be exposed to the working conditions (by introducing it into a pipeline, for example) and the extent of chemical attack determined by periodic examination. If this initial test proves satisfactory, more elaborate tests in which a static load is applied to the laminate under working conditions should be undertaken. Alternatively, it may be possible to go straight to a pilot scale trial with laminate equipment or pipes.

As the amount of experience with laminates in the chemical industry is still small, careful tests should be undertaken before any application is made. The temptation to fabricate the parts oneself should be avoided: they are almost certain to be unsatisfactory unless the correct techniques are employed.

(Acknowledgments are due to the following firms for data used in this article: Bakelite Ltd., Fibreglass Ltd., Leicester Lovell Ltd., Shell Chemicals Ltd.)

*Table 5. Chemical Resistance of a Typical Silicone-bonded Glass Laminate.**

PERCENTAGE INCREASE IN WEIGHT			
Less than 1%	**1-5%**	**5-10%**	**More than 10%**
10% and 30% sulphuric acid.	10% and conc. nitric acid.	Conc. acetic acid.	Conc. sulphuric acid.
10% hydrochloric acid.	Conc. hydrochloric acid.	Solvent naphtha.	Carbon tetrachloride.
10% and 50% sodium hydroxide.	5% acetic acid.	Petrol.	Acetone.
2% sodium carbonate.	10% and conc. ammonium hydroxide.		Toluene.
10% sodium chloride.	Ethyl alcohol Butyl alcohol.		
3% hydrogen peroxide.	Mineral oil.		

*The physical properties of this laminate were as follows: Tensile Strength, 40,000 psi; Modulus of elasticity in tension, 2.7×10^6 psi; Specific gravity, 1.9.

NEW DEVELOPMENTS IN THE DISPOSAL OF INDUSTRIAL WASTES AND EFFLUENTS

TWO important conferences dealing with new developments in the field of effluent disposal were held recently. The first was organised by the Society of Chemical Industry and held in Sheffield.

The second, convened by the Graduates and Students section of the Institution of Chemical Engineers, met in London on April 19-20. The London papers dealt with various sides of this important problem. Thus there were papers dealing with atmospheric pollution, with contamination of waterways by liquid effluent and methods that had been successfully applied to the various problems described.

Features common to most papers were the insistence upon "good housekeeping" as an important measure for reducing the quantities of material requiring special treatment; a further measure of great importance to be taken at an earlier stage is the design of the treatment unit as an integral part of the main manufacturing unit.

The papers dealing with liquid effluents spotlighted the value of microbiological methods, particularly in the treatment of phenolic bearing effluent, where the action of the bacteria is that of an oxidising agent which breaks the benzene ring. In the paper given by Cunningworth a successful activated sludge method of treating bottoms from the ammonia stills was outlined. The method described was capable of reducing the phenolic concentration from around 300 ppm to below 10 ppm, the latter level being considered safe for disposal to the river. A comparison of costs of the various methods that had been tried was given. Thus ion exchange was satisfactory but would have cost about 3s. to 5s. per ton of coal carbonised, whereas the activated sludge method cost only 1d. per ton of coal carbonised. The discussion on this part revealed that the microbiological method was able to reduce concentrations of thiocyanates and cyanides although the work was not sufficiently advanced to give firmer figures for reduction of cyanide concentrations.

A further paper on this subject describing the methods of treating refinery effluent was given by Mr. J. J. Darley, of British Petroleum. This paper brought out clearly the lines of approach to the kind of problem that is encountered at many process plants, as well as illustrating particular methods that have been applied to control various types of refinery effluent.

In developing a treatment scheme the various effluents should be classified according to their properties, and methods of treatment worked out for each kind of effluent. Those operating the plant finally installed were advised to remember that, as a general rule, a method of treatment is applicable only to the specific problem for which it was devised. The need for "good housekeeping," including checks on leakages from pump, glands, valves spindles and pipework joints and so on, was emphasised as was the need to design the treatment plant with the same care and attention as the main production units. The need for a flexible outlook in dealing with such problems has to be related to economic considerations. For example, one must be prepared to modify a production process and so alter the character of the effluent, if the effluent from the original process proved difficult and expensive to treat. In general regenerative methods are more economic than non-regenerative. In the descriptions which were given of various effluents and their methods of treatment, a number of interesting procedures and constructions were described.

Reference was made to the use of the American Petroleum Institute separator for the treatment of the oil-bearing effluent. Sometimes this equipment is incapable of separating finely dispersed oil, and in such cases a kind of air flotation method may be satisfactory. If that method fails, then a chemical method may be called for; this involves the simultaneous addition of lime, ferrous sulphate and alum to the effluent, resulting in a floc which brings down the oil. The cake that results after filtration may then be burnt in suitable furnaces. There is an interesting economic sidelight to the two separation methods just mentioned.

In the case of one refinery, the practice was to return the wet oil recovered to the main crude stream; of the total volume of refined products (3 million gallons per day), 60,000 gallons of product (2%) were provided by the recovered oil.

Dust from Stacks

In a paper dealing with the discharge of solid materials from stacks of a steam-generating plant in a chemical factory, Mr. C. J. Stairmand, of the I.C.I. Engineering Research Department, Billingham, gave a simple classification of air-borne solids encountered in dust reduction problems. This was based upon terminal velocities and resulted in three main groups of particles, with sizes respectively below 20 microns, between 20-76 microns and above 76 microns. The nuisance produced by emission of solid particles could be looked upon as twofold; firstly, it spoils the appearance at the stack and, secondly, it causes

the undesirable deposition of solids over towns and countryside. The aim, therefore, is to reduce both kinds of nuisance. Some interesting facts were given for the quantities of solids which settle out from stack gases. In some industrial areas an average of 64 tons per month of various solids was deposited per square mile, compared with 13 tons at some seaside resorts. De-dusting equipment had been able in some cases to reduce the deposition to around 1 ton per square mile. Mr. Stairmand said that the first cost of the de-dusting equipment can be expected to be something like 10-15% the total cost of the main generating plant, and as the volumes of gas to be handled are large and the pressure losses (25-30 in. w.g.) appreciable in the de-dusters operating costs are also high. He also gave figures for the performance of some de-dusters operating in boilers that employ pulverised fuel and normal solid fuel.

He added that the normal type of cyclone is not a complete answer where pulverised fuel is used, and in such instances one needs to use equipment such as the Venturi scrubber, which is capable of giving a 97% efficiency of removal when handling particles of 1 micron size. However, as this is a liquid scrubber, it has a disadvantage in that one has to clarify the water it uses.

Some of the problems upon which further work is required were pointed to in the discussion on the papers. In the case of droplets—solid particles discharged from stacks—a better understanding of the dispersal and the effect of various climatic conditions is needed. In the case of microbiological methods, work is being carried out on different methods of aeration. Vortex formation by impellers in agitated vessels is being studied, one problem being the difficulty of establishing a stable vortex. More studies in sedimentation properties of solids in liquid effluents and the possibility of pumping sludges were lines of investigation suggested by Professor D. M. Newitt, of the Imperial College of Science, who made the closing speech of the conference.

REMOVAL OF SULPHUR DIOXIDE FROM FLUE GASES

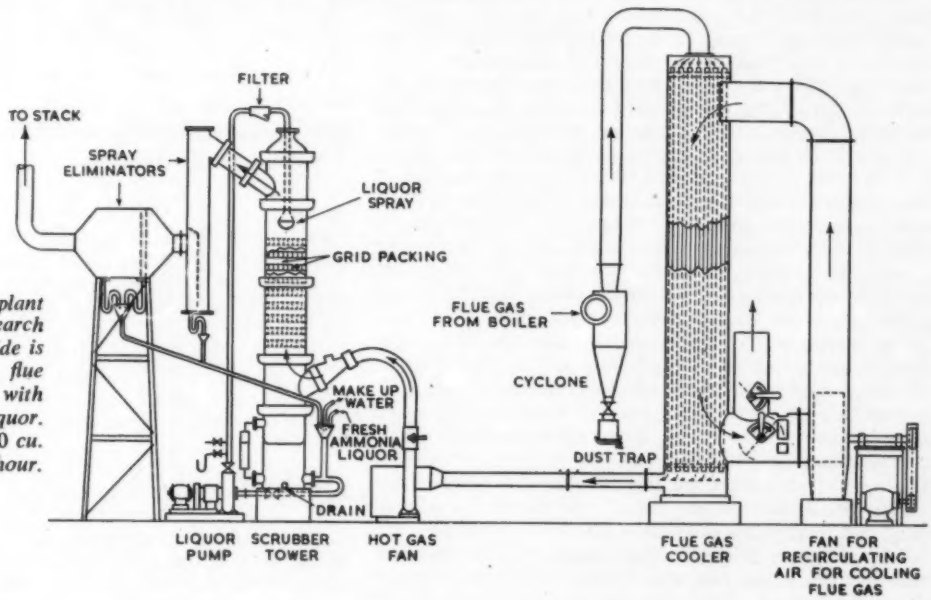


Diagram of pilot plant at the Fuel Research Station. Sulphur dioxide is removed from the flue gases by scrubbing with ammonia gas works liquor. The plant treats 25,000 cu. ft of flue gases an hour.

SULPHUR dioxide, probably the most noxious of the common aerial effluents, is a valuable chemical product. Ideally the process of removal from flue gases should produce this radical in marketable form. The possibilities were highlighted when the by-product ammonium sulphate plant attached to the Nottingham generating station received special mention in the House of Lords by the Government spokesman during the second reading of the Clean Air Bill.

In a paper entitled "Industrial Gases—Recovery of Sulphur Dioxide," which Dr. A. C. Monkhouse and Dr. H. E. Newall presented to the Society of Chemical Industry Conference, the authors attempted not only to assess the relative efficiency of the various processes for the removal of sulphur dioxide from flue gases, but to estimate the approximate cost of the more important processes.

Over five million tons of sulphur dioxide are discharged every year into the atmosphere as the direct result of the combustion of coal, coke and oil fuels. Of this figure, more than a fifth is the responsibility of electricity generating stations and the problem is increasing as power stations change from coal to oil-firing; the consumption of heavy oil for this purpose has trebled in the last three years. For example, a boiler installation burning 2,000 tons of coal a day with a sulphur content of 1.5% is estimated to discharge about 54 tons of sulphur dioxide (assuming 90% of the sulphur is emitted as sulphur dioxide in the waste gases), which is mixed with nearly 1,000 million cu. ft. of flue gas. If fuel oil of 3% sulphur content is used, and if we assume than 1 ton of oil is substituted for 1.5 tons of coal, the equivalent discharge of sulphur dioxide would be 80 tons per day.

The speakers discussed the removal of flue gases under several heads. These included: scrubbing with water; scrubbing with an organic base; scrubbing with an aqueous solution of an inorganic base (e.g. lime, ammonia, magnesia) or with the sulphite of the base; oxidation of the sulphur dioxide to sulphur trioxide by an electrical discharge; and the fixation of the oxides of sulphur as a dry, solid compound.

Sulphur Dioxide from Flue Gases

Washing with water is an obvious method of recovering sulphur dioxide from flue gases, but owing to the low partial pressure of sulphur dioxide the driving force available (the difference between the partial pressure and the equilibrium partial pressure over the solution) is small. It is therefore necessary to use a considerable scrubbing height and enormous quantities of water in order to achieve a reasonable efficiency. Attempts have been made to increase the absorptive capacity of the scrubbing solution by the addition of manganese sulphate, which catalyses the liquid-phase oxidation of sulphur dioxide; however, little success has so far been achieved here on the pilot plant scale. Some success has been claimed in the U.S.S.R. for a modified process using manganese dioxide to oxidise the organic inhibitors present in the flue gases, and concentrations of up to 20% sulphuric acid have been produced.

The use of organic bases, such as anhydrous dimethylaniline, or a dispersion of xylidene in water, have met with little success. There are two reasons for this: the rate of absorption is slow due to the low partial pressure of sulphur dioxide; and a considerable amount of "carry-over" of organic base takes place because of the large volume of flue gas being treated.

Two processes depend on the addition of lime or chalk, which has the effect of reducing the equilibrium partial vapour pressure of sulphur dioxide to the washing water. Both of them have been operated on a full scale. The choice of the process depends on geographical location (i.e., proximity to a large river) and upon whether a closed or open-cycle scrubbing system may be used. At the Battersea coal-fired power station, the open cycle is operated and requires thirty-five tons of water per ton of coal burned. Effluent calcium sulphate is discharged into the River Thames. It is estimated that for any new station that used the Battersea process, the total cost of gas washing would amount to 8s. to 10s. per ton of coal burned.

The closed-cycle system has long been operated at the Fulham generating station and costs at least 12s. per ton of coal burned. One advantage of using the closed-cycle is that it is not essential to site the station near a river as the calcium sulphate is separated out as a sludge.

Magnesium salts by comparison with those of calcium have certain advantages; the sulphite and sulphate are more readily decomposed by heat than the corresponding calcium salts, and magnesium sulphate is much more soluble than calcium sulphate. These factors suggest that it would be better to use either magnesium oxide or hydroxide in a closed-cycle system. Two processes have been tried on the pilot plant scale. In the first, magnesium sulphite is precipitated from the scrubbing liquid, using a suspension of magnesium oxide in water, which is then dried and calcined. Sulphur dioxide is evolved and magnesium oxide recycled. This process, however, requires large quantities of fuel for drying and calcining the sulphite, and involves the handling of large quantities of solid materials. Secondly, magnesium sulphate is treated with ammonia forming ammonium sulphate—a saleable product—and magnesium hydroxide, which is recycled.

The Ammonia Process to be used at Nottingham

A process using an aqueous solution of ammonia has the obvious advantage that the waste effluent is a valuable product, and unit costs decrease as the capacity of the scrubbing plant increases, provided of course that a good supply of ammoniacal liquor is available. At the moment, considerable experience has been gained on pilot-plant and it is estimated that the process can be operated on full-scale at a maximum cost of 2s. 6d. per ton of coal burned. The Fulham Simon-Carves process uses a scrubbing liquor of ammonium sulphate, sulphite, bisulphite, and thiosulphate obtained from gas works. Ash and sulphur dioxide are removed in one operation and gas liquor is added at a rate corresponding to that of the absorption of oxides of sulphur. The final solution is maintained at a *p*H of 5.8 by the addition of a little sulphuric acid. Dust and impurities are removed by filtration before passing the ammoniacal solution at a strength not exceeding 45% ammonium sulphate—to prevent the salts crystallising in the scrubbing tower—to the autoclave, where it is heated to a temperature of 180°C and under a pressure of 200 psi. The ammonium sulphate produced then passes through the conventional crystallisation stages. The Central Electricity Authority is now installing a large pilot plant to treat two million cu. ft. of flue gases per hour at their Nottingham generating station.

Sodium sulphite may be used as another washing medium, but the unit cost per ton of coal burned is greater than the closed or open-cycle processes using lime or chalk. The sodium bisulphite solution produced is treated with zinc oxide forming insoluble zinc sulphite, which is filtered off, and sodium sulphite is recycled. The precipitate is dried and calcined to regenerate zinc oxide and sulphur dioxide. Unfortunately, there is a tendency for the sulphite to oxidise to the sulphate in the scrubbing system.

Oxidation and Electrostatic Precipitation

The oxidation of sulphur dioxide in a silent electric discharge followed by removal of the resulting sulphur-trioxide mist by electrostatic precipitation would be a commercial proposition if cheap electric power were available. Unfortunately this is not feasible in Britain.

Little success has been obtained with laboratory-scale experiments attempting to fix the sulphur dioxide using a dry process. All the washing processes described above saturate the flue gases with water vapour, which has the effect of reducing the discharge into the atmosphere—equivalent to a stack height of the order of 50 feet—which would therefore be overcome if a dry process could be devised.

The ammonia process would appear to offer the greater possibilities. It is lower in operating costs than the others, but it does raise the problem of the availability of very large quantities of ammonia in a particular area. There would also be the difficulty of marketing ammonium sulphate if this process were to be very widely adopted. The economic aspects should not, however, be over-emphasised since the price of imported sulphur may rise. It may be that, in the future, sulphur dioxide from flue gases will make an important indigenous contribution to the production of sulphuric acid in this country in a similar manner to the anhydrite-cement process.

(The figure on p. 99 is based on a Crown Copyright diagram, by permission of the Director, Fuel Research Station.)

Increased production of industrial cuttings oils (and of specialised and general purpose oils also) will result from the re-organisation and expansion programme announced by Amber Chemical Industries Ltd. A new company—Amber Oils Ltd.—has been formed to handle the entire oil side of the original company, the Amber Chemical Company Ltd. To this new subsidiary has been assigned the production and sale of the main types of cutting oil used by industry, of specialised oils and of general purpose oils. Directors closely associated with the present expansion programme are Mr. G. F. Flatow and Mr. H. N. Wigan.

AN EXERCISE IN THE DESIGN OF ABSORPTION TOWERS

by J. McLAREN, B.Sc., F.R.I.C.

IN industry it is sometimes necessary to design equipment when data on the materials to be handled are scant or, in some cases, non-existent. In such cases, a reasonable practical estimate of the size of the equipment required may be obtained by analogy from the properties of materials similar to those which have to be treated. The design of towers for the liberation of cresylic acid from an aqueous solution of sodium cresylate by the absorption of carbon dioxide was an instance where this method was used with success.

At the Midland Tar Distillers', Oldbury Works, in 1946 the sodium cresylate solution, obtained by washing Nos. 1 and 2 primary tar still fractions with caustic soda, was rectified to remove neutral oil and bases and then passed to the cresylic acid springing plant. At this time the latter consisted of three springing towers, one carbonator where the sodium cresylate which remained unreacted was further treated, a separator to allow the sprung tar acids to be skimmed off, and finally a gasser where the skimmed tar acids were further treated to reduce the residual alkalinity to the required value. The tar acid was sprung by reacting it with flue gas containing carbon dioxide. The two reactants flowed counter-current to each other from the carbonator onwards. The latter consisted of a large cylindrical tank in the bottom of which there was a header through which the flue gas passed and bubbled upward through about 4-5 feet of partially sprung sodium cresylate solution. The flue gas leaving the top of the carbonator was led, in separate streams, to the three towers, one stream to each tower. These towers were four feet in diameter and about 40 feet high, each packed to a height of 20 feet with 6 inch diameter by 3 inch deep stacked rings. Over the three towers the rectified sodium cresylate was pumped in three individual streams, one stream to each tower. In the gasser, as distinct from the carbonator and the towers where the flow of gas and liquid is counter-current, the skimmed tar acid is treated batch-wise with flue gas.

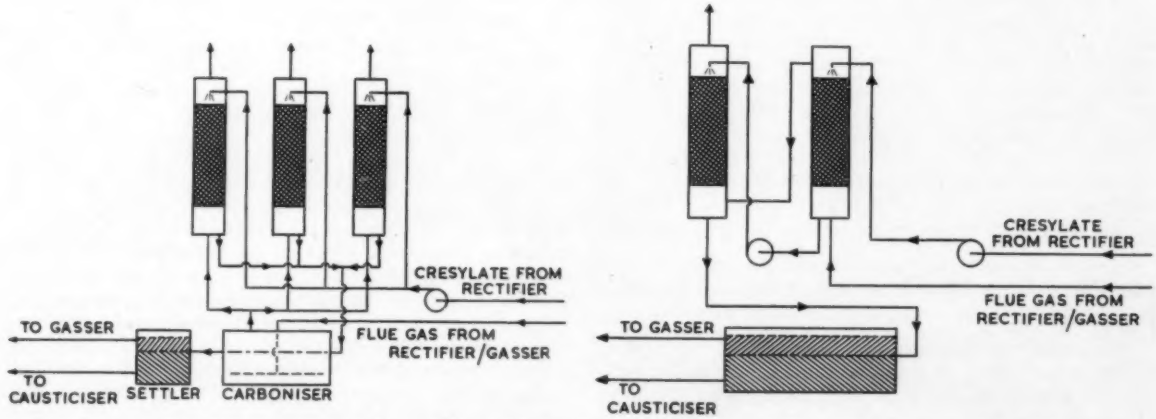
This system imposed a severe back pressure on the flue gas blowers because of the static head in both the gasser and the carbonator. The former head was variable depending on whether the gasser was being used or not, while the latter head was constant. In order to ameliorate this blower duty, it was decided to investigate the possibility of eliminating the carbonator and to spring all the tar acids, except for gassing, in the towers.

In essence the problem was one of absorption and chemical reaction combined. In this particular case it was considered that the mechanism of absorption on the basis of the two film theory was that of physical solution of the CO_2 in the cresylate solution followed by reaction in the liquid film. Experience of CO_2 absorption in the basic solutions,[1,2] where the observed data are explained by combined gas film and liquid film resistance, suggested a similar approach in this instance. Consequently, as shown in the text, the effect of chemical reaction was included in an apparent liquid film coefficient.

The problem therefore was tackled in a straightforward way using the two-film theory

$$\frac{1}{K_g} = \frac{1}{k_g} + \frac{1}{Hk_l} \qquad \text{.....(1)}$$

together with the logarithmic mean driving force and the properties of the proposed packing.



Original arrangement (left) and the revised arrangement of the cresylic acid springing plant.

LIST OF SYMBOLS

K_g = overall coefficient lb./hr./ft.²/atm.
k_l = liquid film absorption coefficient lb./hr./ft.² (lb.ft.³)
k_g = gas film coefficient lb./hr./ft.² atm.
α = constant = 48·6
R_g = gas film packing factor
R_l = liquid film packing factor
C = gas mixture content
v = gas velocity relative to liquid surface ft./sec.
P = total gas pressure (atm.)
$(P-p)_{lm}$ = log mean partial pressure of insoluble gas (atm.)
T_r = Reference temperature (528°R)
T_f = absolute temperature of gas film °R
V = volume of gas (ft³)
v_g = velocity of gas through packing
v_l = liquid surface velocity
V_g = gas rate (ft³/hr.)
ε = voidage of packing
S = Specific Surface area of packing (ft²/ft³)
H = solubility coefficient
H_l = apparent solubility coefficient of CO_2 in 2N sod. cresylate solution
H_w = solubility coefficient of CO_2 in water
D_l = diffusion coefficient cm²/sec.
L = wetting rate ft.³/hr.ft.
d_{rs} = density of soluble gas at R.T.P. lb./ft.³
d = density lb./ft.³
η = viscosity, poise
l = subscript referring to liquid
rl = subscript referring to reference liquid condition
r = " " " " " conditions
f = subscript referring to gas film conditions

Data

Sodium cresylate solution, g.p.h.	= 2800
Sodium cresylate, normality	= 2N
Mean temperature in tower, °C.	= 69
CO_2 in gas entering tower	= 12%
CO_2 in gas leaving tower	= 1%
Density of sodium cresylate, gm/cc	= 1.1

Assumptions

1. The viscosity of the sodium cresylate solution at the mean temperature in the tower was equal to that of a 50% caustic soda solution at the same temperature (ηrl = 1 poise).
2. D_l (the absolute diffusion coefficient) was that for CO_2 diffusing through a water film.
3. The solubility coefficient is the mean of that for CO_2 in water and a modified coefficient for CO_2 in a caustic soda solution of strength 2N.
4. Mean values could be used for the driving force.
5. Tower diameter = 4 ft.
6. Packing = 2 inch dumped Raschig rings. (ε = 0·74)
7. Viscosity sod. cresylate 2N solution = 0·1 poise.

Flue Gas Required

Normality of sodium cresylate solution = 2N. This is equal approximately to 0·02 lb. mol. sodium cresylate per gallon of solution.

∴ lb. mol. of sodium cresylate solution treated per hour = 2800×0·02 = 56

CO_2 absorbed per hour = 56/2 = 28 lb. mol.
Volume of CO_2 to be absorbed per hour = 28×359 = 10,100 cu. ft. at N.T.P.
CO_2 content of inlet gas = 12%
CO_2 content of outlet gas = 1%

Volume of Flue Gas

Let N = lb. mols. of flue gas/hr.
CO_2 balance on the towers is: CO_2 in = 0·12×N, CO_2 out = (N—28) 0·01+28.
Equating and solving, N = 252 lb. mols.
This quantity is saturated with water vapour at 69°C.
Hence total no. of mols. of gas at 69° C

$$= \frac{252\times 30}{30 - 8{\cdot}83} = 352 \text{ lb. mols./hr.}$$

The volume of this gas reduced to the reference temperature of 20° C. = 139,000 ft³/hr

Gas Film Coefficient

This was obtained from

$$k_g = \alpha R_g C d_{rs}\, v^{\cdot 75}\, P/(P-p)_{lm}\; 1/P^{\cdot 25}\; (T/T_f)^{\cdot 56} \quad \ldots\ldots 2$$

(Reference 3, p. 40).
Additional relations needed for the solution of the Equation 2 are

$$v = v_l + v_g \quad \ldots\ldots 3$$

$$v_g = V/3600\varepsilon \quad \ldots\ldots 4$$

In Equation 3 the liquid surface velocity v_l is obtained from the wetting rate-surface velocity graph Ref. 3 (Fig. 15a) and corrected for departure of viscosity and density from the values for water by multiplying by the factor 0·215 $(d_l/\eta_l)^{\cdot 33}$. The wetting rate is given by $L = V_l/S$, and as S for the packing is 28 and the column cross-sectional area is 12·56

$$L = 28000/(62{\cdot}4\times 12{\cdot}56\times 28) = 1{\cdot}28 \text{ ft.}^3\text{/ hr.ft.}$$

From the graph, the uncorrected liquid surface velocity = 0·22 ft./sec.
The corrected surface velocity

$$= 0{\cdot}22\times 0{\cdot}215\ (1{\cdot}1/0{\cdot}1)^{0\cdot 33}$$

$$= 0{\cdot}104 \text{ ft./sec.}$$

The gas velocity relative to the liquid film may now be determined from Equations 3 and 4.

$$v = 139000/12{\cdot}56\times 3600\times 0{\cdot}74 + 0{\cdot}104$$

$$v = 4{\cdot}2 \text{ ft./sec.}$$

Summarising the values for the symbols and groups of Equation 2, we have

α = 48·6
v = 4·2 ft./sec.
c = 0·62 (for mean conditions in tower, see Reference 3, Table 6)
P = 1 atm.
$(P-p)_{lm}$ = 0·93
R_g = 2·7 for 2″×2″×¼″ random-packed Raschig Rings.
d_{rs} = 0·114 lb./ft.³
$v^{\cdot 75}$ = 2·9

$$\left(\frac{Tr}{Tf}\right)^{\cdot 56} = \left(\frac{528}{616}\right)^{\cdot 56} = 0{\cdot}92$$

substitution in Equation 2 gives

$$k_g = 48{\cdot}6\times 2{\cdot}7\times 0{\cdot}62\times 0{\cdot}114\times 2{\cdot}9\times \frac{1}{0{\cdot}93}\times 0{\cdot}92\ \times 1$$

$$= 25 \text{ lb./hr.ft.}^2 \text{ atm. hr.}$$

At that time data on the absorption of CO_2 in sodium cresylate solution was scant and various assumptions were made to determine the over-all absorption coefficient. In particular, it was not known how the presence of liberated tar acids would affect the viscosity of the liquid, and data for the evaluation of the liquid film coefficient was lacking. Finally, the absorption coefficient calculated was corrected by using a modified solubility coefficient. The method used for evaluating the coefficient was a modified version of that described at a later date by Morris and Jackson.[3] However, in the calculation shown their method has been followed.

Modifications Made to Plant Following the Investigation

The above calculation showed that two of the existing towers, each packed to a height of 30 ft., should be sufficient to liberate the tar acids from 2,800 gallons per hour of sodium cresylate.

The old packing was removed from the towers and in each of the latter one inch thick mild steel grids were fitted. The lower grid was fitted immediately above the gas inlet. Water was then poured into the column until it was full. Then 2 in. x 2 in. x ¼ in. stoneware Raschig rings were "floated" down until the column was packed to half its depth. The water was then drained until the top surface of the packing was visible and the second mild steel grid fitted. After refilling the column, the remainder of the packing was installed. The second tower was packed similarly.

Before these modifications were made, trouble had been experienced with the liquid distributor at the top of the columns. These were originally of the umbrella type and the orifices blocked frequently with calcium carbonate from the liquid stream. New distributors were designed, of the skim weir type, and these were installed above the packings in each of the two columns.

Gas from the top of the first column was led to the base of the second and liquid from the base of the first was pumped to the top of the latter so that the system operated counter-currently.

Liquid Film Coefficient

(Ref. 3, p. 17)

$$k_l = 2{\cdot}0\ (d_l/\eta_l)^{\cdot 2}\ D_l^{\cdot 5}\ L^{\cdot 7}\ f(t)\ R_l \quad \ldots\ldots 5$$

where $f(t) = \left(\frac{T}{T_r}\right)^{\cdot 5} \Big/ \left(\frac{\eta_l}{\eta_{rl}}\right)^{\cdot 7}$ $\ldots\ldots 6$

In the above equations cgs units are used; by multiplying the value of k_l by 119 the coefficient is obtained in engineering units.

$\left(\frac{d_l}{\eta_l}\right)^{\cdot 2} = \left(\frac{1{\cdot}1}{0{\cdot}1}\right)^{\cdot 2} = 1{\cdot}02$; $\quad D_l^{\cdot 5} = (1{\cdot}76\times 10^{-5})^{\cdot 5} = 4\times 10^{-3}$

$\left(\frac{\eta_{rl}}{\eta_l}\right)^{\cdot 7} = 10^{\cdot *} = 5{\cdot}0$; $\quad L^{\cdot 7} = 0{\cdot}328^{\cdot 7} = 0{\cdot}46$ (cgs units)

$\left(\frac{T}{T_r}\right)^{\cdot 5} = \left(\frac{342}{293}\right)^{\cdot 5} = 1{\cdot}09$; $\quad f(t) = 5{\cdot}45$

$R_l = 0{\cdot}65$ (Ref. 3, Table 6).

Substituting in Equation 5

$k_l = 2\times 119\times 1{\cdot}02\times 4\times 10^{-3}\times 0{\cdot}46\times 5{\cdot}45\times 0{\cdot}65$

$= 1{\cdot}58$ lb./hr.ft.^{2} (lb./ft.^{3}.)

Solubility Coefficient

The solubility coefficient H is assumed to be the mean of H_w (for CO_2 in water at 69° C.) and H_l an apparent coefficient equal to the weight of CO_2 absorbed by a $2N$ solution of aqueous sodium cresylate solution.

$H_w = 0{\cdot}6$ kg/m^3 atm. (I.C.T. vol. III, p. 260) for CO_2 in water.

$H_l = 44$ kg/m^3 atm.

$\therefore\ H = (H_w + H_l)/2 = 44{\cdot}6/2 = 22{\cdot}3$ kg/m^3 atm. $= 1{\cdot}39$ lb./ft.^{3} atm.

Overall Coefficient

$Hk_l = 1{\cdot}39\times 1{\cdot}58 = 2{\cdot}2$ lb./hr.ft.^{2} atm.

$$\therefore \frac{1}{K_g} = \frac{1}{k_g} + \frac{1}{Hk_l}$$

$$= \frac{1}{25} + \frac{1}{2{\cdot}2}$$

$$= 0{\cdot}04 + 0{\cdot}455$$

$\therefore\ K_g = 2{\cdot}01$ lb./hr.ft.^{2} atm.

Area Required for Absorption

CO_2 to be absorbed $= 28\times 44 = 1230$ lb./hr.

$$\text{Log mean driving force } \frac{0{\cdot}12 - 0{\cdot}01}{\log_e \frac{0{\cdot}12}{0{\cdot}01}} = 0{\cdot}0442 \text{ atm.}$$

$$\therefore \text{Area required with a 25\% safety factor} = \frac{1230}{2\times 1{\cdot}25\times 0{\cdot}0442}$$

$= 17{,}400$ sq. ft.

Height of Packing Required

Cross-sectional area of tower $= 12{\cdot}56$ sq. ft.

Surface area per unit volume for chosen packings $= 28$ sq.ft./cu.ft. (Ref. 3, Table 6).

$$\therefore \text{Height of packing required} = \frac{17{,}400}{28\times 12{\cdot}56} = 50 \text{ ft.}$$

In the original calculations, where a modified method of calculation was used, the packed height was estimated to be 60 ft.

These modifications reduced considerably the back pressure on the flue gas blowers and reduced the tar acid content of the final liquid below that which had been obtained when a carbonator was used. Unfortunately a considerable quantity of lime sludge was deposited on the packing and the efficiency of the system decreased with time until the sludge was removed. The efficiency also decreased when "gassing", i.e., the treatment of the separated tar acid to remove residual alkalinity was in progress, but the exit gas, during continuous test periods, never exceeded one per cent of CO_2.

(The author wishes to thank the Directors of the Midland Tar Distillers Ltd., Oldbury, for permission to use the data in this article.)

REFERENCES

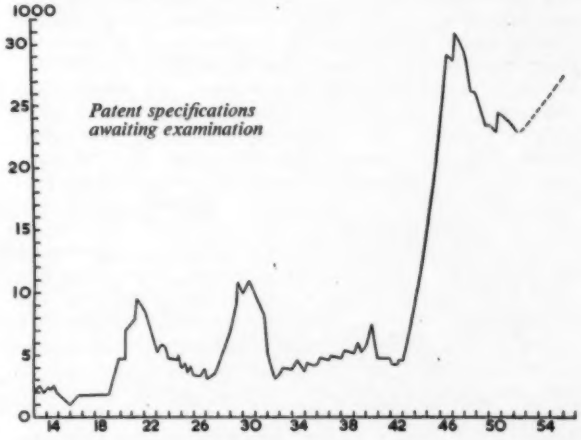
[1] Tepe, G. P. and Dodge, B. F. "Absorption of CO_2 by NaOH solution," *Trans. Amer. Inst. Chem. Eng.*, 1943, **39**, 285.

[2] Cryden and Maloney, J. O. "The Rate of Absorption of CO_2 in diethanslamine solutions," *Trans Amer. Inst. Chem. Eng.* 1947, **37**, 827.

[3] Morris, G. A. and Jackson, J. "Absorption Towers," 1954, Butterworths Scientific Publications, London.

The Queue of Patent Applications

MANY aspects of patent law and practice which affect the chemical engineer were discussed in the paper which H. I. Downes, a Shell patent expert, gave to the Institute of Chemical Engineers recently. He explained why it may take three or four years before an application matures into a patent. There may be an additional period of two-three years or more before a manufacturer can be sure that his plan for industrial production based on a pending patent application will not be obstructed by another pending patent that matures before the one he wants to use. He spoke of the mounting arrears of patents awaiting examination and said that the delays that now occur exceed anything previously known in the history of the Patent Office. The graph shows the trend in recent years; for the years since 1952 he did not give exact figures, but the deterioration of the position which has occurred is indicated by the broken line. Today the arrears amount to between 26,000 and 27,000 applications. He stressed that the Patent Office has never lacked diligence or concern over this. The whole trouble is the difficulty of recruiting Patent Examiners, which is just another reflection of Britain's shortage of scientists and technologists.



Mr. Downes refuted the idea that "know-how" is supplanting patents, and cited the practice of the petroleum industry with which he is associated in support of his view. Asked about the cost of foreign patents, he said that in most countries the figure is about £50-£60. He added that this applied to a country with high patent standards like Germany, and also the Latin American countries where patents are a source of revenue to the State. He was questioned about the protection of patents in countries where they became invalid unless they are used, and he then mentioned the expedient of nominal working to meet such cases. With regard to the principle of "prior publication", he underlined the fact that a trade brochure which was seen by no more than six of the firm's customers could jeopardise a patent, and the same risk can arise with a description that is not actually printed. A distinct improvement in the law from the point of view of chemical engineers is the provision in the 1949 Patents Act which enables the inventor to try out his idea in public to see whether it really works. A good patent can still be secured by making application within twelve months of the trial. He suggested that prior to 1949 many pieces of chemical equipment must have been patented before serious trial.

New Chemical Engineering Course

by E. A. RUDGE, Ph.D., A.M.I.Chem.E., F.R.I.C.

The Government in its White Paper on Technical Education pins great faith on the new sandwich courses now being organised by certain colleges of technology to train technologists. These are being designed so as to qualify students, normally already in industry, for the Hives Award, which will almost certainly be called a "Dip. Tech."—Diploma of Technology. The first course in chemical engineering starts at West Ham College of Technology in September. Dr. Rudge, the college's principal, here describes its content and purpose. The first students will come from local chemical firms and the A.E.A.

FOR many years the West Ham College of Technology has provided courses in Chemical Engineering, both on a full-time and part-time basis. The graduate course for B.Sc. (Chem. Eng.) (Internal) of the University of London conducted by "recognised" teachers has added its small quota to the annual output of technologists. Part-time classes for Post-Graduate Diplomas, for Higher National Certificates, and for the A.M.I.Chem.E. examinations have met the requirements of industry in West Ham and its neighbourhood, and for the training of employees already holding some qualification in engineering or chemistry. Experience has shown that these measures are insufficient in themselves to cope with the ever-growing demands of industry. Good as they are, they provide a mere trickle of new material, and it became imperative that other measures be sought to increase the stream. One measure which has received much attention recently is the works'-based Sandwich Course, and a new scheme of this type has been set up at West Ham.

The problems of industry may best be viewed against the backcloth of the educational system. If we take 100 scholars of the age of 11+, an average of 20 enter the Grammar and five the Secondary Technical Schools. Let us follow these 25 pupils up to school-leaving age. Those in the Secondary Technical Schools normally leave at 16+ with low-grade qualifications, varying from the equivalent of 1st year National Certificate to a few passes at Ordinary Level, G.C.E. These are the lads who become industrial apprentices, pursue part-time studies for National Certificates, and develop into industry's technicians. The Grammar School pupils, about 20 out of the selected 25, follow a system of education which provides for progress through the General Certificate Examinations at Ordinary, and at Advanced Level, up to the age of 18 years. These are the pupils who finally produce the main stream of our graduates, and also form the chief potential source of industrial technologists.

The shortage of technologist-apprentices is without a doubt largely due to a weak link in the chain leading from the 11+ examination to the sixth form of the school, and is best described as the problem of the premature leaver.

The premature Grammar School-leaver is a headache for headmasters the country over, for great numbers of those aged 15 years and upwards drift from the schools into various types of occupation, often with no better paper qualification than a moderate performance in the General Certificate of Education Ordinary Level examinations. Of those who stay on to attain the sixth form of the school, say on an average five to six of the original 20, three or four manage to secure sufficient passes at Advanced Level to qualify for university entrance. Therefore, in broad terms, of every 100 children of 11+, about four reach the university to read for degrees, not only in science and technology, but also the arts, architecture, theology, and so on, whereas about 16 others of Grammar School intelligence but lower attainment drift away into various industrial and commercial occupations.

It appears on this rough analysis that industry is recruiting rather less than 1% of the output of the schools as trained full-time graduates, and perhaps 10% at a lower level whose horizon is no higher than a National Certificate gained by part-time study. Clearly there is a gap to be filled, and an alternative and attractive scheme of training is needed to recruit from the considerable wastage through the schools. This was one of the reasons for the development of the Sandwich Schemes, now running with varying success at many technical colleges throughout the country. Most of them are in branches of engineering, and are local in origin, serving a group of industries around the college. Conditions are very variable, and so are the final standards.

The Government White Paper on Technical Education visualises a Sandwich Scheme with a difference. By setting an entrance qualification equivalent to Advanced Level G.C.E. it will provide an alternative course for those Grammar School-leavers who for one reason or another do not proceed to the university for full-time study. By maintaining a high standard of syllabus, spread over a five-year period, it will ensure an academic level of instruction comparable with that of an undergraduate course. The alternating periods of six months study with six months industrial practice will produce a feed of technologists of the highest quality.

The West Ham Sandwich Scheme in chemical engineering has been designed with these objectives in view. Consultation with the management of leading industries, and with the Ministry of Education, has formed the background of the scheme. The valuable co-operation of British Oxygen (Engineering), and of Boake, Roberts & Co., has helped to produce a syllabus of width and vision, and of high academic value, but with a treatment more suited to the aims of the course.

The bald summary of syllabuses conveys little to the reader. It is sufficient to state that the subjects covered are similar to those of the conventional B.Sc. degree course, with the addition of periods of investigation and research, leading up in the final period to the preparation of a Projective Development Thesis, on the lines of the "Home Paper" of the Institution of Chemical Engineers.

The intention during the formulation of this scheme was to anticipate the required standards of the projected National Diploma Award in Technology. The general syllabus has received the approval of the Education Committee of the Institution of Chemical Engineers, and in due course application will be made to that professional body for recognition of the scheme as a basis for exemption from their examinations.

Provision will be made in the first instance for the enrolment of about 20 students in the first year of the course. In time, increased accommodation and equipment may justify an expansion of the scheme. Although "works-based", the College is prepared to act as a link between industry and the schools at recruitment.

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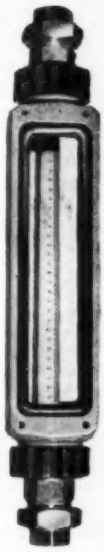

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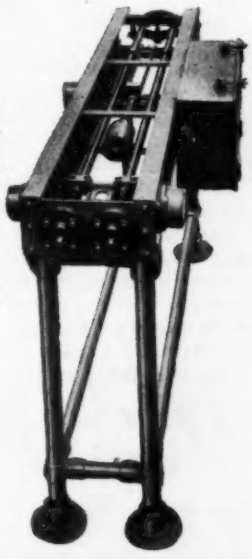

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AMERICAN LETTER

Lithium — A Unique Element

by Dr. Lincoln T. Work

THE post-war period has witnessed a great development of interest in a number of the previously uncommon elements. In addition to uranium and plutonium, elements which have attracted great attention include the rare earths, tantalum, columbium, germanium, titanium, zirconium, hafnium and lithium. Twentyfive years ago less than half of the metals in the Periodic Table were industrially important. Today, the number has doubled. In general, these elements which have newly acquired industrial significance are rarer and more costly, and their applications are more specialised. However, the output of several has reached a substantial volume, and can be expected to increase. One of the most interesting and topical elements is lithium.

With an atomic number of 3 and an atomic weight of 6.940, it is the lightest metallic atom and heads the monovalent alkali metals. This element has the unique property of being an alkali metal, yet differing from the others in this series as to resemble an alkaline earth element with respect to the insolubility of its fluoride, phosphate, and stearate and the low solubility of the carbonate and even the hydroxide. Its high electrode potential and the stability of the carbonate and chloride at high temperatures are also distinctive. Lithium salts increase the fluidity and lower the melting point of molten salts. Ordinary lithium is composed of isotopes 6 and 7, and the lighter of these may be converted to tritium by slow neutron irradiation.

The Germans used lithium in World War I in bearings and in a light strong aluminium alloy. However, its major uses did not develop until the forties, and these are very diverse. They include metal refining, brazing and welding flux, alloys, ceramics, air conditioning, all-purpose lubricating greases, catalysts, organic synthesis, pharmaceuticals, heat transfer, and nuclear chemical reactions. Private industry now takes about 80% of the U.S. output. The more common lithium chemicals range from about 50 cents per pound to a little over two dollars per pound, while the metal and hydride are around 11 and 14 dollars per pound respectively. P. E. Landolt, of the Lithium Corporation of America published the following table giving estimates for the quantities of lithium compounds used in the U.S.A. in 1955 for the various main applications.

	Estimate of 1955 Consumption (as equivalent carbonate)	
	Pounds	*Percentage*
Lubricating greases	3,300,000	39
Ceramics	1,600,000	19
Welding and brazing	1,100,000	13
Air conditioning	1,100,000	13
Alkaline storage batteries	610,000	7
Pharmaceuticals	30,000	—
Other	760,000	9
TOTAL	8,500,000	100

Since 1951, there was roughly a four-fold increase in the quantities used in lubricating greases, welding and brazing, and air conditioning, a two-fold increase in ceramics and alkaline storage batteries, and no appreciable change in pharmaceuticals. The same author has given figures that indicate how the consumption of lithium metal has expanded.

World production until 1942 was less than 5,000 pounds per year. The war years saw an increase in the United States up to about 100,000 pounds per year. Then there was a drop in demand, but the level of consumption afterwards rose and today it is higher than the wartime maximum.

Over 100 Lithium Minerals

Lithium occurs in some measure on all of the continents, Its primary minerals are: spodumene, a lithium aluminium silicate containing 4-7% Li_2O; lepidolite, a lithia mica containing 3-4% Li_2O; and petalite, a modified spodumene, having from 2-4% Li_2O. Besides amblygonite, a fluoro-aluminium phosphate containing 7-9% Li_2O, and zinnwaldite, which is a modified lepidolite, there are well over 100 other minerals containing lithium.

In this growing phase, the lowering of product cost brings new applications which were not previously economical, and the margin for operations becomes closer. The low percentage of lithium oxide in the ores makes it necessary to mine large quantities for a given production, and loss of yield may be great at this first stage. Concentration by flotation and with heavy media is employed to bring the lithium content to a level which permits chemical refining. In other cases, hand-sorting of ores achieves the same end. There is one other source, namely a lithium sodium phopshate of 20-22% Li_2O content, which is derived from desert brines. Since it is the by product of other operations, the available quantity limits this to a small but substantial fraction of the annual business in lithium chemicals.

Recovery processes must be cheap since the concentration is low. One method involves heating calcined spodumene with sulphuric acid and leaching out lithium sulphate. This solution is purified and lithium carbonate is precipitated with soda ash. Other methods of extracting lithium from minerals involve calcining with lime or with potassium sulphate, then leaching and purifying. In view of the tonnage of ore handled, there was one proposal to use calcium chloride with a lithium-bearing cement composition and to volatilise the lithium chloride while making cement clinker.

Maywood Chemical Works was the chief producer of lithium metals and chemicals prior to World War II. They had a rich source of ore in South Dakota and also used some lithium sodium phosphate from brines of American Potash and Chemical Corporation. The annual capacity was approximately 1,000,000 pounds expressed as lithium carbonate. During the war, the over-all U.S. capacity increased to 4,000,000 pounds of lithium carbonate per year, and Foote Mineral Company and the present Lithium Corporation of America became factors. The post-war drop to almost pre-war levels has been followed by a substantial growth which, by 1952, had reached the wartime peak and is now far in excess of that. Levels of 15,000,000 pounds as lithium carbonate are now the order and a two- or three-fold increase seems likely. American Potash and Chemical has also become a factor. Lithium Corporation with operations in North Carolina and South Dakota as well as a source of Canadian ore and Foote Mineral Company with a mine in North Carolina are leading factors. This is a currently rapidly growing business, still very much in a state of flux.

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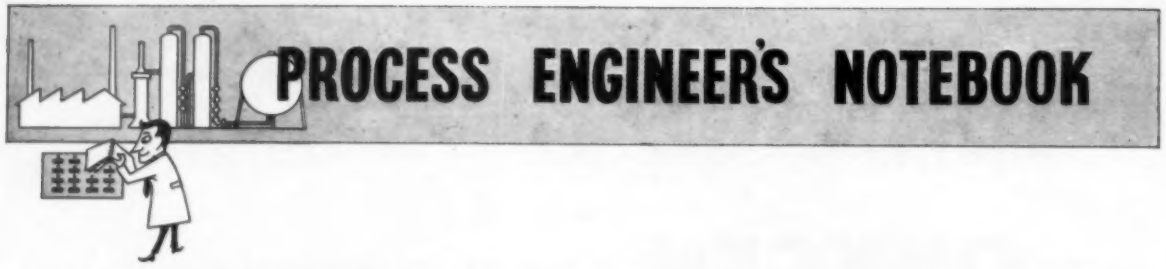
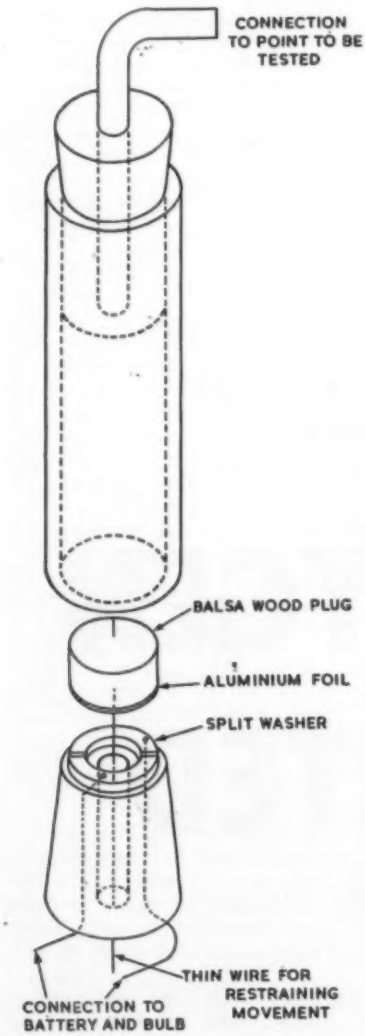
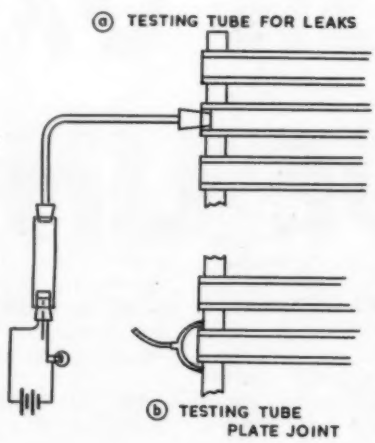


Leak Testing of Heat Exchangers

THIS is a gadget whose purpose is to detect leaks in vacuum or pressure systems, particularly in heat exchangers. It consists of a balsa wood plug to which is glued a thin disc of aluminium foil (e.g. a milk bottle top), which rests metal-surface downwards upon a metal washer that has been sawn in half. This is glued to the end of a cork bored to the size of the washer opening. The two halves are separated and the gap filled with adhesive. Wires are soldered to the underside of each half of the washer and are threaded through the cork. The ends are wired to a pocket flash-lamp battery in series with a flash-lamp bulb. The cork is pushed into a glass tube in the manner shown, with the plug resting upon it. The upper end of this tube bears a connection, whose extremity may carry a cork for insertion in a tube; alternatively a rubber cap may be used for testing the joint between tube-plate and tube.

A leak causes a flickering of the flash bulb or its extinction. To test for a leak the appropriate end is greased and applied to the suspected tube. If the leak is a bad one the lamp will flicker immediately; otherwise it may be advisable to restrain movement of the plug until sufficient evacuation in the system has taken place for the plug to lift and interrupt the electrical circuit. By inverting the assembly, it is possible to indicate leakage where the exchanger is under pressure, although this is generally satisfactorily carried out with soap and water. It is necessary that the working faces of plug and split washer seat properly, and for this reason both faces should be lightly ground with fine grinding paste. It is important that the cement build-up between the two halves of the washer should stand proud of the washer before this is done.





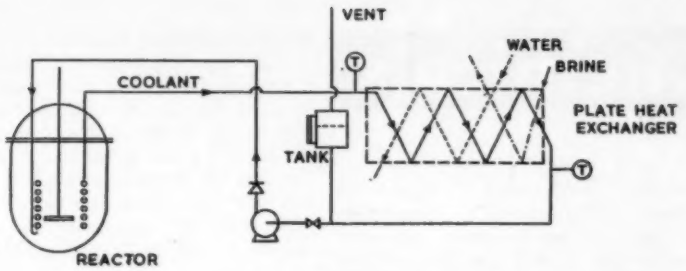
Mass Spectrometer Solves Extraction Problem

Following the use of a new calcium nickel-phosphate catalyst, a well-known Canadian company experienced a falling-off in the performance of the solvent extraction unit for butadiene. A mass spectometer quickly revealed the presence of water soluble carbonyls in the gases leaving the reactor, the carbonyls upsetting the efficiency of the extraction solvent. By installing a water scrubber before the extraction unit the carbonyls were removed and the butadiene satisfactorily separated. Speed was the keynote of the investigation and was made possible by the use of the spectrometer.

Safe Removal of Heat of Reaction

THE arrangement here was worked out to provide a safe means of removal of heat of reaction from batch or continuous reactions, where either or both of the following considerations apply: 1, The reactants are corrosive; 2, Normal methods of cooling (such as circulation of water or brine) involve a hazard because the cooling medium in contact with one or more of the reactants would set off another highly exothermic reaction, or would upset the reaction and result in the wastage of valuable products. Such conditions would apply to many organic reactions, such as those involving the use of oleum, concentrated sulphuric acid, phosphorus oxychloride, organic acid chlorides, and similar chemicals.

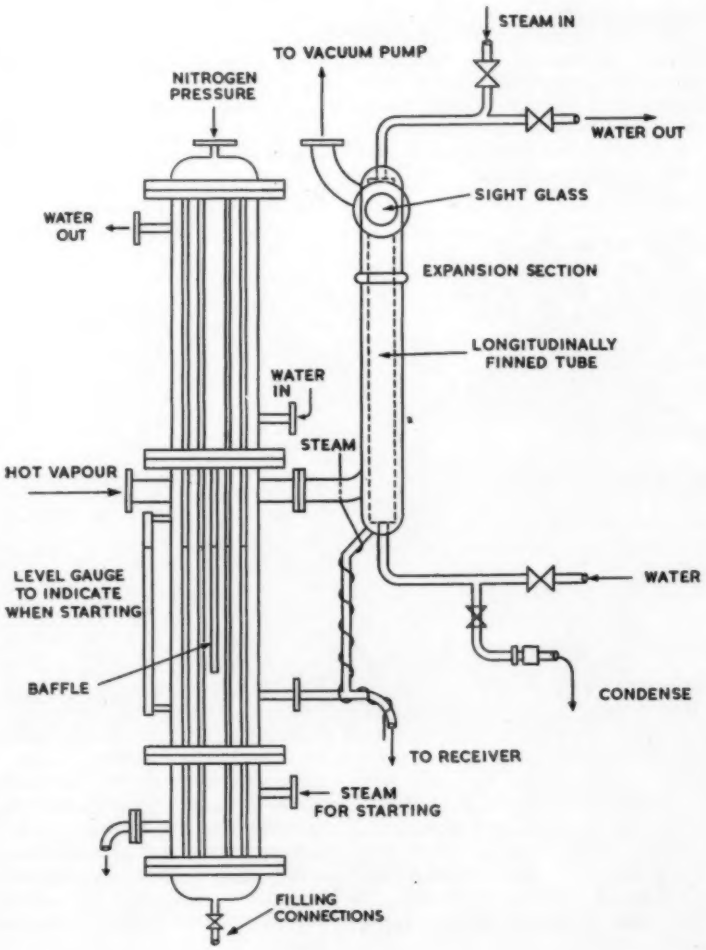
Normally water or brine would be circulated through the coil or jacket of the reactor. In this case a liquid medium harmless to the reactants is circulated through the cooling coil. For example, if the reaction is carried out in a medium such as monochlorbenzene, then this liquid can be used as the cooling medium. It is a minor disadvantage in most cases that the required circulation will be greater than with aqueous cooling media on



account of the lower heat capacity of such organic materials.

A plate heat exchanger through which direct cooling is applied, either by brine or water or both, is the means by which heat is removed from the reactor-cooling medium. Sometimes, where the reactor permits some measure of water cooling, it is advantageous to let water remove some heat from the reactor-cooling medium, and to get the desired final temperature by means of brine. This system has the advantage of economy in refrigeration in cold weather when the water temperature is low.

A small tank is provided in the reactor-cooling medium line on the suction side of the pump to accommodate changes in specific volume of the reactor-cooling medium. This tank is arranged so that the cooling medium in the exchanger may be drained back into it. Further, since the level of the contents of this tank would be under constant observation, any leakage at the coil or jacket of the reactor would become evident. The plate exchanger has advantages in this case over normal types of exchanger; it has greater flexibility, and is more easily arranged for coping with the small temperature differences called for in such an application.



Condensing System for High Boiling Point Substances

THIS arrangement of condenser and after-condenser was devised to overcome line blockages in a high-temperature vacuum-distillation process. In the latter, an organic sulphonyl chloride was distilled in order to reduce its content of a higher boiling impurity. The reboiler was connected to a condenser with three compartments, the object of this set-up being to prevent condensation at or below the triple point of the chloride, and to maintain the condensate in a liquid condition.

The temperature of the condensing agent, which, in this case, was carbon tetrachloride, was set by adjusting the tube-side pressure at the top connection of the three compartment condenser. The after-condenser was added to reduce carry-over of condensible material by incondensible gases, and to reduce contamination of the intercooler water of the two-stage steam ejector set, which was used as the source of vacuum. Further, operation without the after-condenser would have resulted in blockage in the vacuum piping system after several hours running, and would have led to serious interruption in production while the lines were being cleared. The after-condenser was connected both to a supply of water for cooling and to a supply of steam which could be applied to the condenser when required.

With the after-condenser in use, it was found necessary to stop distillation for short periods once or twice per day. On these occasions water flow to the after-condenser was interrupted and steam applied. The solid material, which had accumulated and threatened to block the system, was thereby melted and run by gravity into the distillate receivers.

In the construction, the cooling tube was a length of longitudally finned tube with dual sight glass placed about two-thirds of the condenser length from the bottom of the assembly. This was originally intended to provide for inspection of the cooling surface so as to give the operator some warning of the onset of a build-up of solids. In practice, the glasses tended to fog before the loss of vacuum in the system became excessive, and this occurrence was therefore used to indicate the right time for stopping the distillation process. During the heating process at the after-condenser, the film of material on the sight glass became molten and drained to leave a clear view of the internal heating surface (see diagram left).

World of Chemicals

Argentina's Oil and Gas

Two oil and one natural gas pipelines are planned by the Argentina Government. The pipelines are due for completion in five years and it is hoped that the resultant crude oil production will total some 10 million tons a year. This should make Argentina self-sufficient.

Extrusion Mill for Venezuela

The Aluminum Corporation of America have announced that they intend building an extrusion mill in Venezuela. Exact site and date for erection have yet to be decided.

Russian Intermediates for India

Rusian experts are investigating the possibilities of manufacturing intermediates for the Indian pharmaceuticals and dye stuffs industry. A six-man team are now in New Delhi and will visit factories throughout India during the next three months.

Iraq Oil Find

Oil of excellent gravity has been struck at Sassan a few miles northwest of Tel Afar, north Iraq.

Pharmaceutical Import Increase

Pharmaceuticals figure prominently in Ethiopia's import returns, rising from 2,102,240 Ethiopian Dollars in 1953/54 (Britain 20%) to 2,262,154 last year (Britain 20%). The Italians are still the leading suppliers with the Americans, Germans and French also exporting large quantities to Ethiopia.

B.P.'s Bitumen Plant

The bitumen plant at B.P.'s Kwinana Refinery, Western Australia, has produced over 12,500 tons of bitumen since it was commissioned in July last year. The bulk has been used for the construction of new roads and the repair of existing roads in Western Australia during the current road-making season.

U.S.A., U.K. and China

U.S. Department of Commerce has temporarily withdrawn U.S. export privileges from two London firms for failure to answer questions concerning U.S.-origin commodities sold to China. The first suspension concerns 55 metric tons of boric acid valued at $7,500 and the second suspension involves a similar but unrelated transaction in which the firm is believed to have sold to China aureomycin worth some $43,000. U.S. export regulations embargo all shipments to China where a firm refuses, without adequate reason, to answer proper questions concerning its knowledge and participation in a diversion of U.S. goods.

German Oil Developments

Esso is to construct a new oil refinery at Cologne with a throughput of 3 million tons, and designed to produce a large volume of fuel oil. Shell is also reported to be planning large-scale extensions to its Harbung plant. The Gelensenberg Co., is planning for an increase from its refinery, the capacity planned for being some 3 million tons. B.P., Deutsche Erdol, Mobile and Perfina are also understood to have development plans under consideration or are actively engaged on new extensions to plant.

Turkey's Refinery

The Turkish Batman oil refinery—officially opened on 1st January—hopes to process 250,000 tons of crude oil this year. The refinery's intake is expected to increase to some 350,000 tons of crude on completion of the Garzan-Batman pipeline (35 km.) during 1956.

German Aid for Rhodesia

German experts of the Lurgi-Rhurchemie are to provide technical assistance to the Lubimbi Coal Areas Ltd., Rhodesia, in their investigations into the possibilities of producing oil from coal. Preliminary moves in this endeavour have been reported as satisfactory.

Radioisotopes and Fertilisers

Radioisotope studies of fertiliser efficiency promise savings of the order of $10m. a year, through the improved methods of placing the fertilisers and timing their application, estimates Dr. W. F. Libby, U.S. Atomic Energy Commissioner.

Tobacco Smoke and Cancer

Two known carcinogens have been identified in tobacco smoke, but whether they have a direct role in producing lung cancer has not been proved, stated the Minister of Health, Mr. Turton on 8th May. The same day a joint statement issued by leading British tobacco firms stressed that experimental evidence is lacking to show that tobacco smoke causes cancer.

Australian Carbon Black

The managing director of the Shell Chemical (Australia) Pty. announces that in association with the United Carbon Company, of West Virginia, a £A2m. plant will be built at Geelong for the manufacture of carbon black for the Australian rubber industry. The plant will save Australia about £A2m. a year in foreign exchange.

Uganda Fertilisers

A new company registered in Uganda in January will, it is believed, be associated with the Uganda Development Corporation in the production of fertilisers from the apatite deposits at Sukulu.

Jamaican Bauxite

Reynolds Jamaica Mines Ltd. are expanding their bauxite plant. Alumina Jamaica Ltd. also have an expansion programme. Bauxite production in Jamaica will increase from 230,000 to 543,000 tons a year when these plant extensions are complete.

Oil from Egmanton

B.P.'s oilfield at Egmanton, Notts., discovered a year ago, now produces about 1,000 tons of oil a month from six wells. Another well is being drilled, and derricks are being erected to drill two more. The nearby Eakring oilfield is producing 53,000 tons a year.

French Petroleum Chemicals

Output of petroleum chemicals at the Naphtachimie plant near Lavera Refinery Marseilles, is to be increased. The plant is being converted to use either a light naphtha or gasoline feedstock. Ethylene capacity will go up to 18,000 tons, and propylene to 18,000 tons.

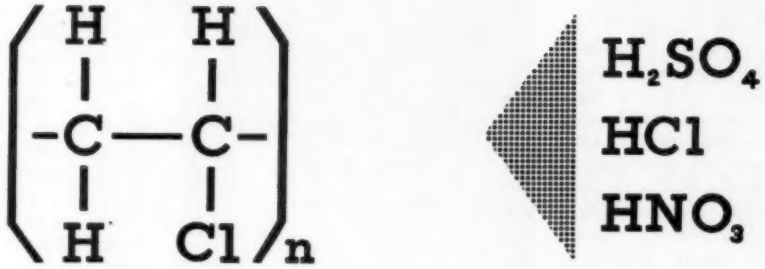
Kroners from Fertilisers

Norsk Hydro, Norway's largest industrial concern, the main product of which is nitrogenous fertilisers, is to increase its share capital by 50%, making a total of Kr.238m. The turnover last year, when the company celebrated its diamond jubilee, exceeded Kr.400m.

Plastics from Petrol

Plans for two factories are announced by France for the production of, respectively, synthetic resins and insecticide from petrol. The factories are to be built in the Marseilles region. Reports state that synthetic resin production will meet the requirements for the French market, and that of the insecticide, sufficient to cover the requirements of Mediterranean countries.

There's a chemical cold war between



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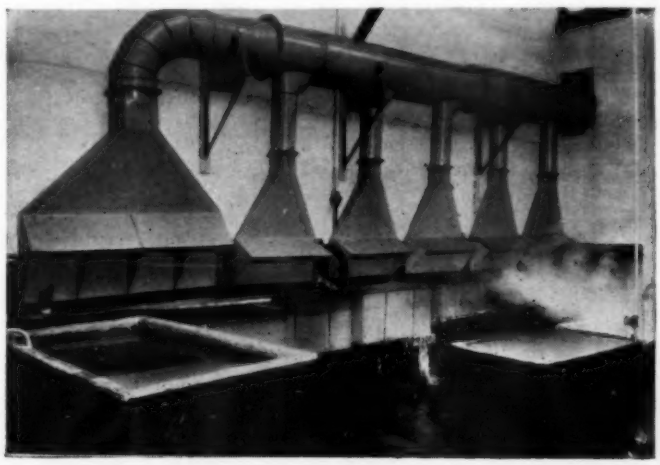

This Acid Fume Exhaust Unit in Cobex vinyl sheet was manufactured by Horwitch Smith & Co. Ltd., for Ewarts Ltd. Dudley.

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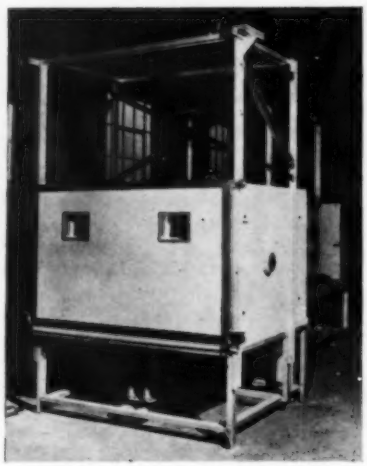
Builds and Insulates in One Operation

All types of ovens, driers, curing tunnels, lehrs, kilns and similar units have been made in "Marinite" for the bakery, textile, plastic, rubber, aluminium and glass industries. As it does not warp under heat, it is also used extensively for foundry core plates and launder linings. The new material, "Marinite", is a good insulator and can therefore be used wherever heat insulation is a problem. Apart from the uses outlined above, "Marinite," cut to special shapes, is used as heat insulating pads for supporting glass during heat treatment processes, and for heat insulation pads in foundry work. **Marinite Ltd., 114 & 116 Park Street, London, W.1.**

BCE 126 for further information



Small Mobile Hydraulic Platform

The newly-introduced small model of the Simon Hydraulic Platform should find many uses within the chemical industry. It has a maximum working height and radius of some 10 ft. less than those of the Company's standard model and it can be mounted on a considerably smaller carrying vehicle. It can, therefore, be used in places too cramped for the 5-ton commercial chassis on which the standard model is normally mounted, and its cost is also substantially less. Maximum horizontal extension is 15½ ft. from the turntable centre to the front of the platform, giving the operator a working radius of some 17½ ft. Maximum working height is approximately 30 ft. above ground, depending on the height of the carrying vehicle. With the outrigger jacks in use, the maximum platform load is 500 lb.

Operation is entirely hydraulic, and most of the main working parts are self-lubricating. All platform movements are normally controlled from the platform by the operator. Duplicate controls are fitted on the turntable. The unit includes a number of safety precautions; for example, should the hydraulic pump stop or fail, the platform stays in position until lowered by the operator. Descent is at a safe speed even if a hydraulic line should break and an automatic cut-out stops motion when the platform reaches set limits. **Simon Engineering (Midlands) Ltd., Queens Cross, Dudley, Worcestershire.**

BCE 129 for further information

Filter for Very Fine Filtration

The Stellar Filter of the Paterson Engineering Company Ltd., has been specially developed for use where a very fine filtration is required. The filter consists essentially of a cylindrical shell and outlet manifold constructed to take Stellar patented wire-wound elements. The element consists of a tube with equally spaced longitudinal ribs having a screw-thread cut along the entire length, providing on each rib a series of grooves in which the consecutive turns of wire wound on the ribs is firmly located. The openings over the whole area of the element are of regular size and the result is a rigid element with the shortest possible flow and the minimum gap. The regularity of the openings ensures an even coating of filter aid with no break which would permit unfiltered liquids to by-pass.

As regards materials of construction, filter shells for general purposes with aqueous liquids are made of mild steel and lined when necessary with a hard plastic enamel. For foodstuffs and corrosive conditions, stainless steel is used. The filter elements for water, oils and non-corrosive liquids are made with extruded brass tubular cores, electro-tinned and wound with either Monel or stainless steel wire. **Paterson Engineering Co. Ltd., Windsor House, Kingsway, London, W.C.1.**

BCE 128 for further information

Power-Driven Emulsifier

A power-driven emulsifier with a wide diversity of use, including the preparation of pharmaceutical products, cosmetic creams, cream fillings as used in the bakery and confectionery trades, ice-cream mixes and cream from fresh milk or dried skim milk and butter, has been announced. The Bel emulsifier, powered by a ½ h.p. motor and having a 1-gallon container for holding the mix, is reported to give outputs of up to 15 gallons per hour. **British Emulsifiers, Hook Rise, Kingston By-Pass, Surrey.**

BCE 127 for further information

"Forjend" Assists in Lining-up Pipework

It is often necessary to erect petroleum and chemical installations very close to the main superstructure of plant or walls of buildings. Fittings marketed under the name of "Forjend" make this possible using only girth welds, and greatly assist in laying out and lining-up of pipework. Flanges, elbows, tees and reducers are constructed in accordance with BS. 1560 and 1640. Sections are at least full pipe thickness, without thinning at the backwall, and are therefore made of uniform thickness. Tangent design makes it unnecessary to weld on a curved section. **Talbot Stead Tube Co. Ltd., Green Lane, Walsall.**

BCE 130 for further information

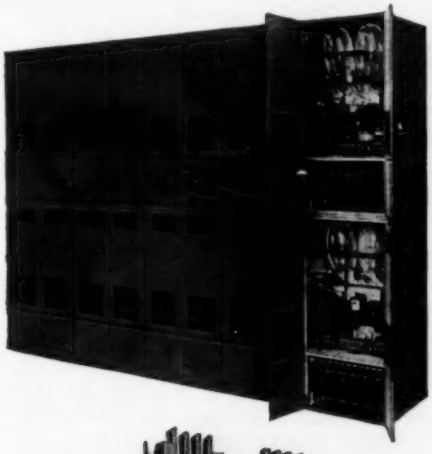
60,000 amps

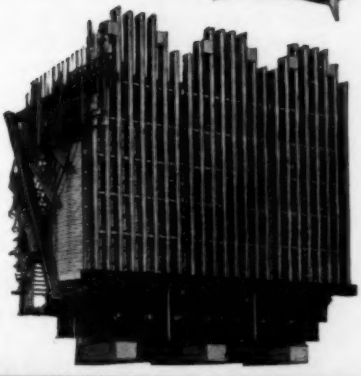
250/500 volts D.C.

in one installation

Hewittic Rectifiers

handle any capacity





This record size installation of Hewittic rectifiers provides a continuous D.C. output for a large electro chemical plant. The same skill and attention to detail is devoted to the manufacture of all types of Hewittic rectifiers, and this equipment—by far the largest glass bulb rectifier installation in the world—serves to emphasise the supreme reliability and high efficiency of the Hewittic rectifier and its complete suitability for handling any capacity that may be required.

The photographs on the right show, *top*, one of the banks of Hewittic rectifiers depicted above and, *bottom*, a view from the secondary side of one of the main transformers for this installation.

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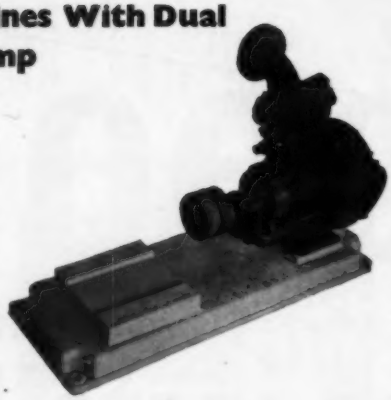
Easy Priming on Drag Lines With Dual Action Pump



This piece of equipment is essentially two-pumps-in-one. The first is a vacuum pump, and the other a centrifugal pump; these operate from a common shaft. This dual action enables easy priming on dry lines or with volatile liquids. The piston vacuum pump creates a vacuum in an air release chamber (fitted with a float) connected to the suction inlet. The production of a vacuum causes the liquid to be drawn up to enable the centrifugal pump to function in its usual way. When fully operating, the liquid level in the release chamber causes the float to close the connecting line to the vacuum pump which, however, continues to idle. If the air or vapour enters with the liquid, the float lowers with the liquid level; the vacuum pump then continuously removes the air or vapour as it accumulates, and discharges it. Consequently the pump will operate even with a leak in the suction line and is automatic in operation independently of dry or flooded suction conditions. This pump is particularly suitable for petroleum and other volatile liquids. **Wayne Tank and Pump Co. Ltd., Newlands Park, London, S.E.26.**
BCE 131 for further information

New Seal Dispenses With Stuffing Boxes

The sealing of pumps handling petroleum and chemical products is often difficult. The Rotary Magnetic Seal is a new mechanical seal which entirely dispenses with stuffing boxes and packing materials and can be used for shaft diameters from ¼-7 in. Coolants are unnecessary as the friction heat is conducted through the magnets directly to the shaft and pump body. The magnets are constructed of circular steel rings, with a carbon rotating sealing face. Thus the magnetic field is a closed circuit and no static electricity is generated. Seals are already in commision working at pressures from 25-250 psi and vacuums from 0-25 in. mercury, and being of metallic construction excessive temperatures present no difficulties. **The Rotary Magnetic Seal Co. Ltd., 10 Barton Street, Bath, Somerset.**
BCE 134 for further information

Density Meters Suitable for Slurries

The new "RM" density meter has been successfully used for controlling the density of abrasive and clay slurries. The RM continuously weighs a loop of pipe through which liquid flows. It provides outlet air pressure (3 to 15 psi) having linear relations to fluid density range normally 0.2 g/cc. The calibration is simple to check and adjust, requires the minimum of maintenance and is easily cleaned when plant is shut down. **Rotameter Manufacturing Co. Ltd., Purley Way, Croydon, Surrey.**
BCE 132 for further information

Space Limited—Use Tel-O-Set

For graphic panels or where space is limited, Tel-O-Set recorders, indicators and controllers offer many advantages. Their quick connecting mounting, unit construction and versatile operation are only three of the attractive features of these recently introduced instruments. Regarding the latter facility, the recorder chassis remains fully operative while completely or partially withdrawn and a horizontal scale above the chart provides continuous indication of control air pressure even when the chassis is completely removed. Automatic chart re-roll gives 30-day process records. **Honeywell - Brown, 1 Wandsworth Road, Perivale, Greenford, Middlesex.**
BCE 133 for further information

Expansion Joints for Pipe Movements

The recent introduction of butt-welded tube has considerably eased the cost of fabrication of Teddington Aircraft Controls Ltd.'s stainless steel bellows. Thermal expansion and pipework movement often cause considerable trouble in the chemical, gas turbine and atomic energy fields and can only be solved by using an expansion joint—normally of bellows type—constructed in stainless steel or other suitable corrosion-resistant alloy. These bellows are at present made in Britain in diameters up to 7 ft. The Solar Aircraft Company, of America, an associate company of T.A.C.'s, have engineered one in stainless steel, 28 ft. in diameter.

Other applications include exhaust systems for flexibly mounted engines and generator and boiler uptakes for large marine engines. **Teddington Aircraft Controls Ltd., Cefn Boed, Nr. Merthyr Tydfyl, Glamorgan, S. Wales.**
BCE 135 for further information

Soil Resistance

Before carrying out a cathodic protection scheme for buried structures and pipelines or determining the corrosion characteristics of various soils, it is necessary to measure the soil resistivity over a wide range. This can very conveniently be determined using the Tellohm Soil Resistivity Meter, which is completely portable and weighs 20 lb. Power supply is by standard dry cell, within the case. **Nash & Thompson Ltd., Oakcroft Road, Chessington, Surrey.**
BCE 136 for further information

Ultrasonic Thickness Gauge

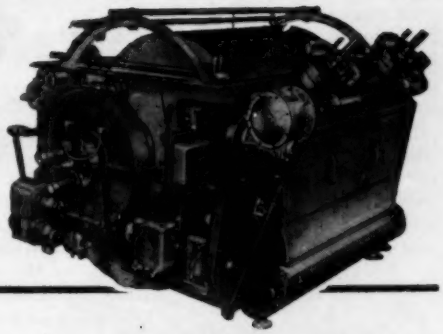
Extending their range of ultrasonic thickness gauges, a new model, the Type 1107B Visiguage, has been introduced by Dawe Instruments Ltd. This operates on the ultrasonic resonance principle by which the thickness of components can be measured. Direct-reading scales are available for the measurement of thicknesses between 0.005 in. and 2.5 in. with an accuracy of between ±0.0005 in. and ±0.003 in. **Dawe Instruments Ltd., 99 Uxbridge Road, London, W.5.**
BCE 137 for further information

EIMCO

Filters for every Process industry

PRE-COAT FILTERS

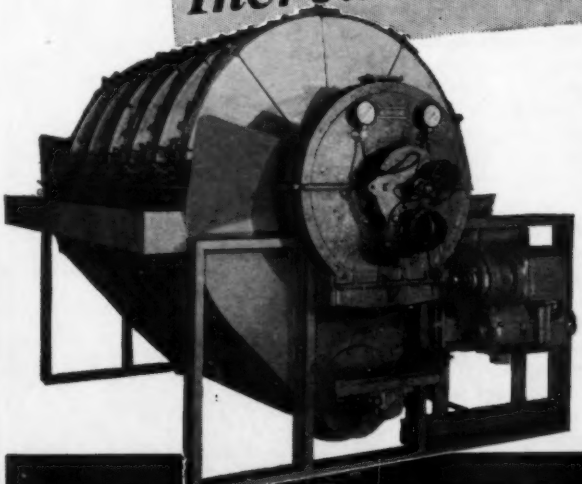
Are basically of drum design but have an automatic advancing knife for keeping the pre-coat material open for free filtration, particularly suitable for removing slimes or colloids.



EIMCO TUBULAR FILTERS

Available in sizes up to 1,000 sq. ft. of filter area. Especially adaptable to water clarification, breaking emulsions treating boiler feed water etc., where a high flow rate must be maintained and a sparkling clear filtrate is a necessity.

Increase filter capacity 20% per sq. ft. area



EIMCO AGIDISC FILTERS

Give clean cake discharge.

Provide even distribution and evenly distributed particle size over the entire disc filter surface.

Increase tonnage and reduce moisture content.

Especially suitable for the metallurgical and mining industries.

Send us your problems or write for further details

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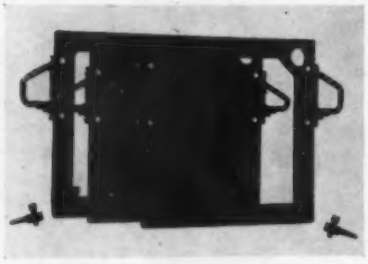
London Office: PRINCES HOUSE, PICCADILLY, W.1. GROsvenor 2184

2538

Resin Laminated Wood Plant

By impregnating the cell structure of wood with phenol-formaldehyde resin its disadvantages — dimensional instability and susceptibility to bacterial and insect attack—are overcome. Mechanical strength, especially across the grain, has been considerably improved. B.H. Permali has good resistance to common acids up to 20% but is not recommended for use in contact with sodium hydroxide solution stronger than 5%. The illustration shows a plate and frame filter press plate. These can be made in all sizes up to 20 sq. ft. in area without metal reinforcing. They have been used for filtering paints, dye-stuffs, syrup and a wide range of chemical solutions. Other proven applications



include: fume hoods and ducting, agitators and impellers, submerged bearings and many chemical containers. **Permali Ltd., Gloucester.**
BCE 138 for further information

Self-Contained Packaged Boilers

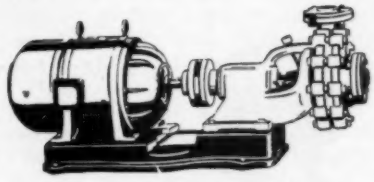
Packaged boilers which are complete steam producing units in which the boiler, fuel burner, draught system, feed water and oil service tanks are self-contained on one chassis. Very little installation is required and a range of capacities are offered in both horizontal and vertical boiler forms to obtain the maximum output from the minimum space available. The Spanner range are oil-fired, use Swirly-flo patent firetubes, and can be automatically or hand controlled. Heat transfer between the hot gases and the tube wall is considerably improved by the use of these helically grooved tubes. Brickwork is unnecessary as all the furnaces are water cooled. **Spanner Boilers Ltd., 258 Brixton Hill, London, S.W.2.**
BCE 139 for further information

Liquid Protective Coatings for On Site Treatment

A new addition to the neoprene surface coating range has been announced by Prodorite. The material is available in two forms: a maintenance grade, air cured, for the protection of steelwork, concrete structures and plant; and a special quality grade, heat cured, for greater chemical corrosion and temperature resistance. An adhesion-bond strength of up to 1100 psi can be obtained over the temperature range −60°F to 250°F. The coating is easily applied by hand after shot-blasting or other suitable surface preparation, and is especially useful for "on site" treatment of the large vessels much used in the petroleum and chemical industries. **Prodorite Ltd., Eagle Works, Wednesbury, Staffs.**
BCE 140 for further information

Centrifugal Pump with Removable Impeller Head and Shaft

These horizontal non-priming centrifugal pumps are constructed for easy removal of the tapered impeller for which a range of sizes can be supplied. In this way the duty is varied for a given pump, without the interchange of any other components. Mounted on bearing brackets, the Labour Type DZT pump is normally driven through flexible couplings but other types of drive may be used. Only one shaft seal is fitted so that vulnerability to wear and corrosion is reduced to a minimum. A variety of packing glands and packings are available and these may, in most cases, be provided for water sealing or water



cooling or both. This pump, using stainless steels and high nickel alloys for construction, is especially suitable for handling a wide range of acids and corrosive liquids. **British Labour Pump Co. Ltd., Blundell Street, London, N.7.**
BCE 141 for further information

Balanced Mechanical Seal for Use with High Corrosive Fluids

The Teflon balanced mechanical seal is designed for high temperature and pressure work and for use with highly corrosive fluids. It is directly interchangeable with the Flexibox synthetic rubber fitted seal. The Flexibox RRTCQ fitted seal is suitable for fitting inside the standard stuffing boxes of most types and sizes of modern centrifugal pumps. It also finds application for rotary positive displacement pumps and for the agitator shafts of high pressure autoclaves.

A heavy-gauge stainless-steel wire spring drives the two-part rotary seal ring positively but resiliently, and is surrounded by a circulating fluid to prevent the formation of gummy deposits between the coils. Leakage along the shaft sleeve in either direction is prevented by means of a Teflon sleeve, which is situated between the two parts of the rotary seal ring. A Teflon seal supports the stationary seal ring in the cover.

Extreme conditions of 250°C temperature and stuffing box pressures of 800 psi can be tolerated by the seal in its standard form. Higher temperatures can be handled with circulation coolers. **Flexibox Ltd., Nash Road, Trafford Park, Manchester 17.**
BCE 142 for further information

"9-Group Protection"

solves Corrosion problems

In finding the right answer to many different plant-protection problems, St. Helens have developed nine comprehensive groups of natural rubber and synthetic compounds, including :

1: NATURAL RUBBER
In various anti-corrosive grades for general application under temperature conditions up to 160° F. (70° C.).

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St. Helens will be pleased to advise as to the most suitable compound for your particular purpose.

Please ask for literature or send details of requirements.

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This is the fan that resists the chemical action of strong acids, alkalis and moist gases. Steel outer casing. Impeller constructed from rigid P.V.C. and all metal surfaces protected with same material. We design and install complete plants including P.V.C. Ducting and Hoods. Let us have details of your requirements.

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The Month's News in Brief

News Briefs

At the invitation of the Academy of Sciences of the U.S.S.R. the Royal Society is sending a delegation to Moscow under the auspices of the Soviet Relations Committee of the British Council. The delegation left on the 18th May, 1956, and will spend a fortnight in the U.S.S.R. visiting scientific institutions. Included in the delegation are Professor J. M. Robertson, F.R.S., Professor of Chemistry and Head of the Chemical Laboratories of the University of Glasgow; Professor M. Stacey, F.R.S., Professor of Chemistry in the University of Birmingham; and Dr. D. C. Martin, Assistant Secretary of the Royal Society. Lord Adrian, O.M., the immediate Past-President of the Royal Society, will lead the delegation.

British Petroleum are to pay the University education fees and some other expenses of selected young men wishing to become technologists, and at the same time pay a salary of £350 a year.

A.B.C.M. have set up a Chemical Engineering Research and Advisory Service Committee. The chairman is Mr. E. W. Greensmith, of I.C.I. Ltd. The A.B.C.M. members are Dr. J. W. Barrett, Monsanto Chemicals; Mr. F. Mackley, Shell Chemical; Mr. K. Piercy, Albright and Wilson; Dr. F. Roffey, Distillers Co., and Mr. B. E. A. Vigers, Laporte Chemicals. The B.C.P.M.A. have appointed Mr. G. A. Dummett, of A.P.V. and chairman of its research committee, as its liaison member. Dr. E. H. T. Hoblyn, director of B.C.P.M.A., and Mr. J. Davidson Pratt, director of the A.B.C.M, are *ex officio* members. Mr. Trefor Davies is the committee's Technical Executive Officer.

British Oxygen Chemicals announce that their polyvinyl acetate (PVA), an important chemical for the plastics industry, will in future be known as Vandike.

On 7th May, 1956, Pascall Engineering moved to their new works in Gatwick Road, Crawley, Sussex.

I.C.I. Ltd. have announced a final dividend on the Ordinary Stock of the Company of 6%, making with the interim of 4% a total of 10% for the year 1955 (the same as for 1954). The group's consolidated sales for 1955 amount to £411 million, a record total.

The use of a site at Winfrith Heath, Dorset, is being considered by the A.E.A. for an extension of the type of research activity which is carried on at Harwell. There is no intention whatsoever in the minds of the Authority of putting experimental reactors on the Winfrith site and letting them "run away."

The production capacity and machinery of the Wimbledon factory of Compoflex Co. Ltd. are being transferred to the main Compoflex factory at Huddersfield Road, Oldham.

Babcock & Wilcox announce the formation of a Materials Handling Division to co-ordinate in one group the various functions hitherto performed by separate departments. The new division will be officially formed in June, and will be accommodated at Lynton House, Tavistock Square, W.C.1 (Phone EUS. 4321). Its manager will be Mr. F. S. Stent and its chief technical adviser Mr. R. A. Taylor.

The Board of Trade announces revised conditions for the remission of the duty chargeable on imports of machinery under Section 10 of the Finance Act, 1932.

An agreement to produce new types of polyolefin plastics has been signed by Pullman Incorporated, of which the M. W. Kellogg Co., is a subsidiary, and Phillips Petroleum Co. The Phillips process employs a new type of catalyst. Besides producing a new type of polyethylene, the process will result in a new spectrum of resins from olefins being made available from the petroleum industry.

A **Japanese** Government research scientist has found a method of producing graphite from coal. Great importance is attached to the discovery since it is estimated that if mass production can be applied to the process, the graphite (indispensable to the generation of atomic energy) could be made for about Y200,000 per ton, two-thirds of the prevailing international price.

Atomics

During their recent visit to Britain, Marshal Bulganin and Mr. Krushchev toured Harwell. The Russian party, among whom was Academician I. V. Kurchatov, the Russian atomic expert, was officially received by Sir Edward Plowden and Sir John Cockcroft. Our picture shows the Russian guests in the chemical engineering laboratory, Harwell.

The Turkish Minister of Education has announced that efforts are being made to establish two atomic research reactors in Turkey.

A special committee for Nordic co-operation on peaceful uses of atomic energy is to be established. Countries involved are Denmark, Finland, Iceland, Norway, Sweden.

Electricite de France has announced its intention of constructing its first big atomic power station at Pont-Boulet on the Loire. Construction is expected to take three years and to cost 40 milliard francs. Production is expected to be 60,000 kW. after 18 months and 300,000 kW. finally.

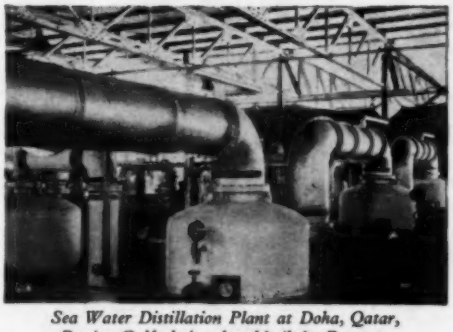
Preparatory work on the site of a 400,000 kW. atomic power station is now under way near Moscow.

Costain-John Brown are to act as advisers to the Indian Atomic Energy Department for heavy water produc-

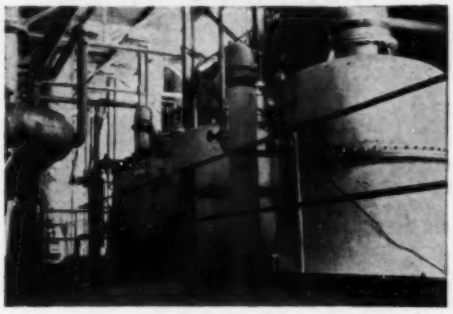
Bulganin, front right, listens to one of the chemical engineering experts at Harwell. On his right stands Academician Kurchatov and Krushchev.

BCE 108 for further information

Bring Water TO the Wells!



Sea Water Distillation Plant at Doha, Qatar, Persian Gulf, designed and built by Bennetts.



The incompatibility of oil and water is nowhere more eloquently exemplified than in the Petrol-bearing lands along the Persian Gulf. Here wealth beyond avarice is poured out every year from a terrain so parched and barren that the amenities of civilised living are made possible only by recourse to the most advanced techniques of modern science. Even indispensable water has to be brought to these arid wastes by distilling salt water from the sea—*main* water, indeed, but with a difference.

Sea Water Distillation is one of those incredible processes which have enabled man to circumvent the local niggardliness of nature and to bring into productive use vital resources hitherto untapped; processes which have made the desert, in the words of the prophet, "blossom like the rose."

Bennetts are pioneers in this as in other fields. We have not only kept abreast of the latest developments but have originated a great many of them. Our reputation is world-wide.

BENNETTS

Designers, Manufacturers and Suppliers of Distillation Plant and Equipment.

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- ★ *Guaranteed recooled temperature*
- ★ *Completely Splashless operation*
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- ★ *More efficient cooling*
- ★ *Lower pumping head*
- ★ *Minimum running costs*
- ★ *Less ground area*

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BCE 109 for further information

tion and a fertiliser factory.

The U.S. Atomic Energy Commission announces that it has removed the "secret" label from 10,916 research and development reports.

A committee has been set up by the Minister of Commerce to investigate and report on the division of responsibilities in the development of nuclear energy for civil purposes in Sweden.

America is to help Siam in developing atomic energy for peaceful purposes. An experimental atomic reactor will be part of the aid.

Suitable legislation to govern the exploitation of uranium, some deposits of which have already been discovered in Chile, is under consideration.

People

Sir Henry Tizard, G.C.B., A.F.C., F.R.S.—director of Glaxo Laboratories Ltd., and Solway Chemicals Ltd., and a member of the National Research Development Corporation, and **Mr. Frank Schon**—chairman of Marchon Products Ltd., and Solway Chemicals Ltd., have been appointed to the Board of Albright & Wilson Ltd.

Sir Henry Tizard *Mr. Frank Schon*

Mr. J. K. Batty, joint managing director of the Alkali Division of I.C.I., has been appointed Alkali Division chairman, in succession to **Mr. W. M. Inman**, who retired from the Company's service on 29 February last.

BISRA Council has appointed **Dr. J. Pearson**, M.Sc., Ph.D., F.R.I.C., as assistant director of Research, to assume such duties as are delegated to him by the Director, **Sir Charles Goodeve**. Dr. Pearson will continue his present duties as Head of BISRA's Steelmaking Division and Chemistry Department.

The Hon. J. K. Weir has relinquished his position as joint managing director to become chairman of the Weir Group of Companies. **Mr. J. Russell Lang** has been appointed sole managing director of G. & J. Weir Ltd., and **Sir Charles Connel**, M.A., chairman of Charles Connell & Co. Ltd., has been appointed as a director.

The National Coal Board has appointed **Dr. Leonard Charles Tyte** to be Director of their Mining Research Establishment at Isleworth, Middlesex. Dr. Tyte is responsible to the Director General of Research, **Dr. W. Idris Jones**, at Headquarters.

Measuring Instruments (Pullin) Ltd. announce the appointment of **Mr. W. T. Shelton**, A.M.I.E.E., as chief development engineer.

Raymond Stevens, a vice president of Arthur D. Little, Inc., Cambridge (Mass), since 1930, became its third president in seventy years, succeeding **Earl P. Stevenson**, the new chairman of the board.

Christopher J. Pratt has returned to the Filter Business. He has joined Dorr-Oliver in the U.S., from the Association of British Chemical Manufacturers; previously he assisted in the formation of E.I.M.C.O. (Great Britain) Ltd.—Filter Division.

Sir Ben Lockspeiser has joined the board of Tube Investments and has been appointed Scientific Adviser to the Tube Investments group. Sir Ben recently retired from the Department of Scientific and Industrial Research.

Sir Bernard Keen and **Mr. A. G. P. Powell** have been elected to the board of Baird and Tatlock (London) Ltd. and **Mr. W. C. Johnson** and **Mr. H. N. Ricketts** have been elected to the board of Hopkin and Williams Ltd.

Dr. Roger G. Bates, leader of the National Bureau of Standards *p*H standardisation programme, has been awarded the 1955 Hillebrand Award by the Chemical Society of Washington.

At a meeting of the board of directors **Mr. D. R. Mackie** was appointed managing director of Monsanto Chemicals.

Dr. James I. Hoffman will head the National Bureau of Standards Metallurgy Division. He succeeds **Dr. John G. Thompson** who recently retired.

At the Annual General Meeting of the Institute of Petroleum the following were elected: president, **The Rt. Hon. Lord Geddes**; vice-presidents, **E. LeQ. Herbert** and **R. B. Southall, C.B.E.**; member of council, **M. E. Hubbard**.

At the Annual General Meeting of the British Electrical Development Association, **Viscount Chandos** was re-elected president for the year 1956/57.

The following were elected as vice-presidents of E.D.A.: **H. J. Randall**; **S. F. Steward**; and **E. R. Wilkinson** (all former chairmen of E.D.A. Council); and **Mr. E. H. Mullens**. At the first meeting of the new Council, **Mr. D. Bellamy** was elected chairman, and **Mr. W. S. Lewis** (B'ham) vice-chairman for the current year.

F. E. Warner *A. L. Whynes*

The Institution of Chemical Engineers held its 34th annual meeting in London on 24th April, Mr. John A. Oriel presiding. The following elections were made: *President:* Mr. John A. Oriel; *Vice-Presidents:* Mr. G. U. Hopton, Professor H. L. Roy, Mr. P. K. Standring, Dr. A. S. White; *Jt. Hon. Secretaries:* Mr. F. E. Warner, Mr. R. C. Odhams; *Hon. Treasurer:* Mr. F. A. Greene; *Council Members:* Mr. J. S. Brough, Dr. B. Edgington, Dr. J. F. C. Gartshore, Mr. L. W. J. Loveless, Prof. F. Morton.

At the end of the meeting the president presented medals as follows: *Moulton Medal* to J. S. Forsyth and J. T. Wood; *Junior Moulton Medal*, A. L. Whynes; *William Macnab Medal*, John Duncan Howie. At the annual dinner Mr. Oriel presented the Osborne Reynolds Medal to Mr. F. E. Warner for his services to the Institution especially as joint honorary secretary.

The Minister in Charge of C.S.I.R.O. (**Mr. R. G. Casey**) announced today the appointment of the following new members to the Advisory Council of C.S.I.R.O. Included among these are: **Mr. M. A. Mawby**, vice-chairman of Consolidated Zinc Pty. Ltd. and Commissioner of Australian Aluminium Production Commission; **Mr. W. W. Pettingell**, general manager, The Australian Gas Light Company; **Mr. E. M. Schroder**, managing director, Adelaide Cement Company Ltd.; **Mr. H. B. Somerset**, managing director, Associated Pulp and Paper Mills Ltd.; and **Dr. J. Vernon**, Senior Executive Officer, Colonial Sugar Refining Company Ltd.

In our last issue

In the Nomogram article, Figs. 5 and 6 were unfortunately transposed; in the fourth paragraph, p. 41, the penultimate sentence should have read "The lines AG and BH have been constructed parallel to DEF". The second sentence of the article "Potentialities of Viscosity Control" should have read "With the former, viscosity is a constant at any particular temperature. . . ." In "Process Engineer's Notebook" we referred to "rotameter" in the generic sense (i.e. a variable area meter). No reference to an instrument made by Rotameter was intended.